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THE JOURNAL OF THE SOCIETY OF AUTOMOTIVE ENGINEERS

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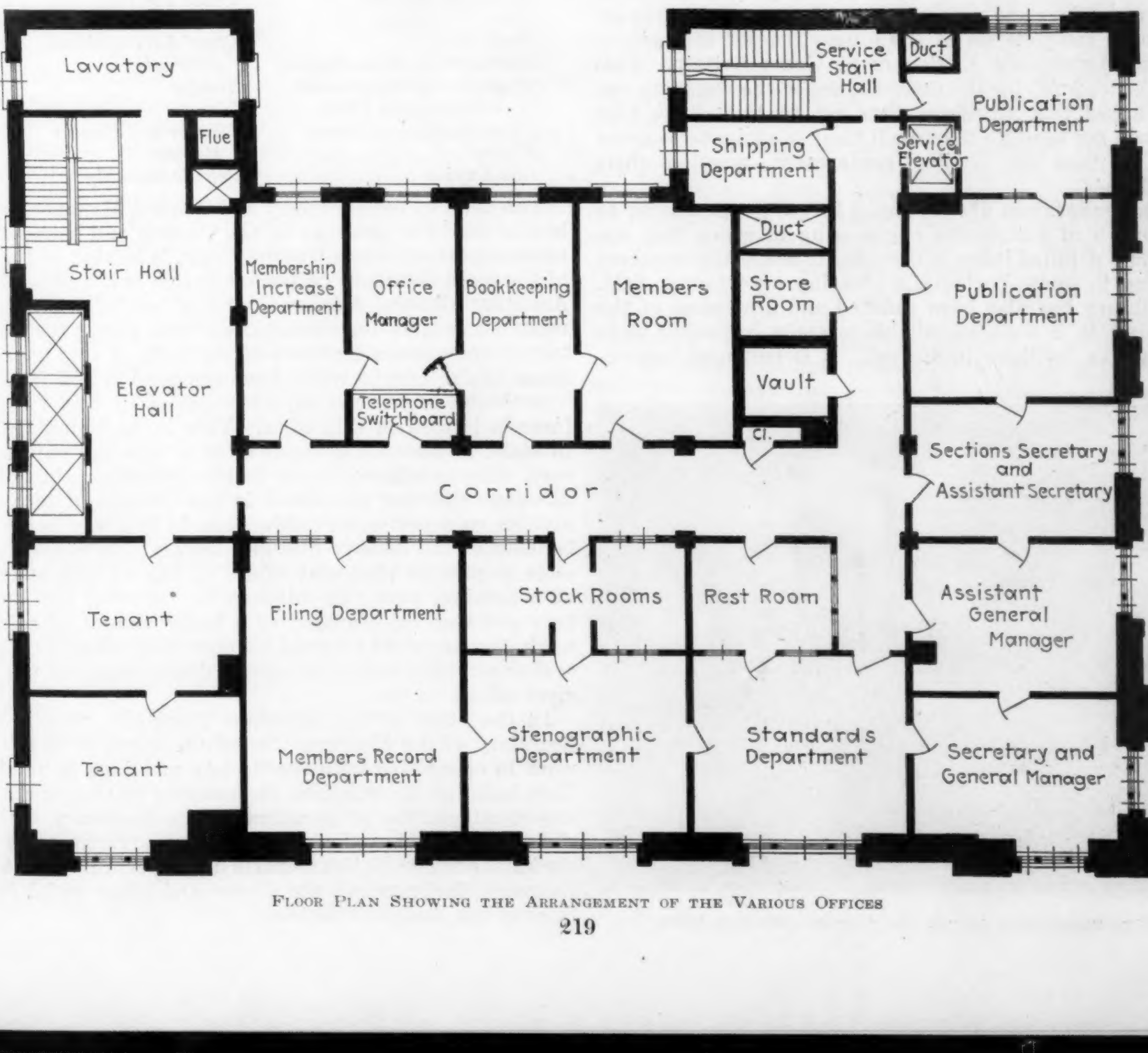
Offices of the Society

THE increase in the various activities and membership of the Society in the last two years has been reflected in the volume of work that the office at New York City has been called upon to handle. This has resulted in an expansion which made the securing of larger quarters necessary. In September 1918 the Society occupied practically the entire office space on the sixth floor of the Engineering Societies Building, 29 West Thirty-ninth Street, New York City, an area of approximately 3800 sq. ft. On May 1, 1920, the seventh floor in the same building was secured, where the area available for offices is approximately 7500 sq. ft. The offices having practically double the area of the former ones on the sixth floor are very much more satisfactory as regards the distribution of space as well as being better suited to the character of the work which the various branches of the Society staff are called upon to do. In assigning the space to the various departments, as shown on the accompanying floor plan, consideration was given to the amount of contact which they had with each other in order to arrive at an arrangement reducing waste steps to a minimum.

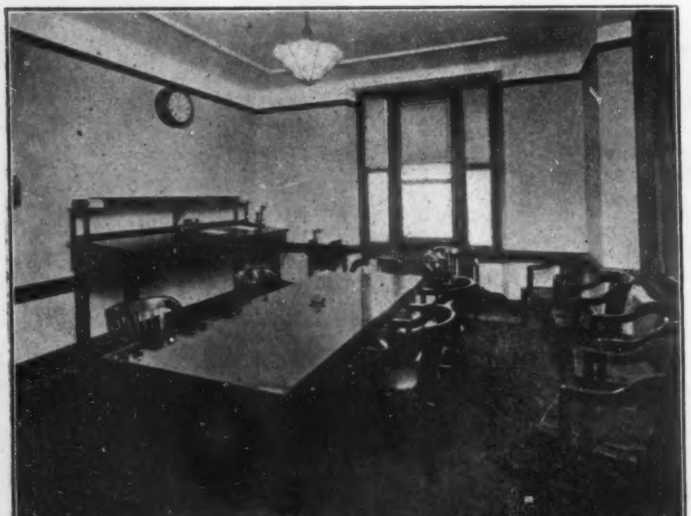


FLOOR PLAN SHOWING THE ARRANGEMENT OF THE VARIOUS OFFICES

THE MEMBERS' ROOM

As a member leaves the elevator on the seventh floor, he is greeted by the clerk at the Information Desk. If, as sometimes is the case, the member of the staff whom it is desired to consult is engaged at that particular moment, a commodious Members' Room has been provided where the visitor can wait. In this room will be found facilities for writing, racks in which approximately 100 technical publications of this and other countries can be found, and bookcases containing books on various branches of automotive engineering, as well as bound volumes of *The Transactions*, THE JOURNAL, and technical magazines and proceedings of technical societies, including a complete set of the proceedings of the Institution of Automobile Engineers of Great Britain. This room is designed for the exclusive use of the members and it is hoped that whenever they are in New York City they will not hesitate to make it their headquarters, using it as a place for holding conferences, meeting their friends, etc.

These magazines are arranged in groups according to the branch of automotive engineering to which they apply and a detailed index is provided to assist the members desiring to locate periodicals covering a particular field. The library has also been indexed and a member of the organization is always available to assist in finding technical works for those interested. It is pertinent to mention at this time that the numerous trade and technical papers received by the Society are always carefully searched by members of the staff for material which is considered of interest for publication in THE JOURNAL. The reports of those Government bureaus, such for example as Bureau of Standards, National Advisory Committee for Aeronautics, National Physical Laboratory of Great Britain, etc., whose research work is of value to automotive engineers are filed carefully and are also covered in the indexes. These many facilities of the Members' Room considering also the valuable Engineering Societies Library in the same building are most appreciated by members undertaking research work and study. If demand warrants the Members' Room may be kept open after regular office hours.



THE SECRETARY'S OFFICE AND COUNCIL MEETING ROOM

Some of the engineering periodicals that are regularly received, in addition to the journals of the different engineering societies are given below:

Aerial Age
Aeronautics
Aircraft Journal
American Machinist
Automobile Engineer
Automobile Topics
Automobile Trade Journal
Automotive Industries
Aviation
Chemical and Metallurgical Engineering
Chilton Tractor Journal
Commercial Vehicle
Cooper's Vehicle Journal
Electrical Review
Electric Vehicle
Engineer
Engineering News-Record
Engineering Supplement of the London Times
Farm Implement News
Flying
Gas Engine
India Rubber World
Iron Age
La Pratique Automobile
La Vie Automobile
Light Car and Cycle Car
Machinery
Motorcycle and Bicycle Illustrated
Motorship
Motor Traction
Motor Truck
National Petroleum News
Petroleum
Power
Power Boating
Power Wagon
Royal Aeronautical Journal
Rudder
Tires
Tractor and Engine Review
Vehicle Monthly

The office of the Secretary and General Manager, which is also used for meetings of the Council and some of the more important committee meetings, is located at the end of the main corridor. Adjacent to this is the office of the Assistant General Manager, who is located so as to be readily available for consultation with either the Secretary or the various members of the staff. A very complete index of the articles which have appeared in *The Bulletin*, THE JOURNAL and the various volumes of *The Transactions* is located in this office. This index is maintained to assist in answering inquiries of a technical nature, all such correspondence being handled through this office. Members desiring assistance in the location of technical articles on a particular subject can in this way enjoy the benefits of the Society files and library. It is even possible to provide photostat copies of any of this material at a nominal cost. In addition to relieving the Secretary and General Manager of a large amount of routine work, the Assistant General Manager also exercises a general supervision over the various departments of the Society offices.

In the office of the Assistant Secretary, who is also Secretary of the Meetings Committee, much of the detail work in connection with the Society meetings is handled. This includes, for example, the securing of the papers for the meetings, the preparation of the necessary lantern slides to accompany their presentation, arrangements for the hotel accommodations, sports and entertainment at the Summer Meetings and the dinner and other social functions at the Annual Meetings.

The Employment Service of the Society is also under the jurisdiction of the Assistant Secretary. This is intended to benefit all who make use of it, whether employer or employe. While the work consists primarily of the insertion of notices in the "Men and Positions Available" columns of each issue of THE JOURNAL, numerous details, such as conferences with members looking for positions and with others looking for men, are handled here together with the forwarding of replies that are received, as well as endeavoring where possible to notify members who have registered at the office of openings for which they appear suited before these notices are published in THE JOURNAL, and replying to requests received from employers. The members of the Society are entitled to the insertion of a "Men Available" notice in THE JOURNAL for three months in any one year, and the use of the "Positions Available" section is open to any reputable employer. Members and the companies they represent can do the Society, themselves and their fellow members a real service by informing the Society office promptly of any opening for men of engineering or related experience which may come to their notice and they are therefore urged to write the Society immediately when new men are needed, and also to request their company's employment manager to do likewise. On an average one application per day for the past year has been received from members who actually need positions, and practically all of these applicants have been placed. The number of positions for which employers are seeking men that are referred to the Society's Employment Service, of course, varies with the season of the year, but the average in this case is practically the same.

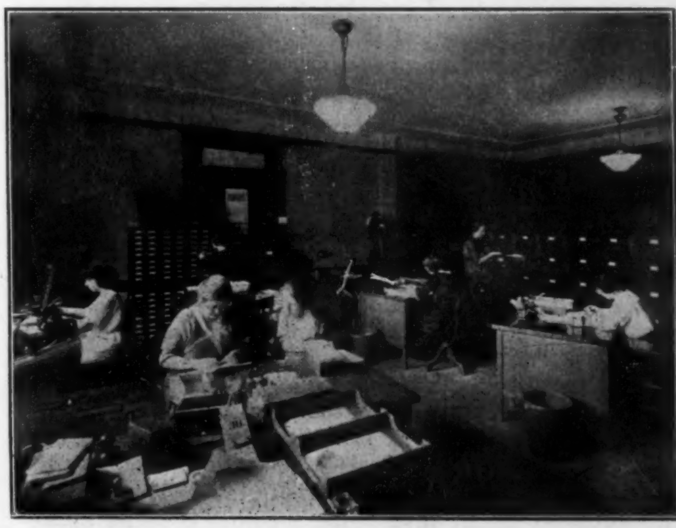
The Sections Secretary, who is also located in this room, is the link between the office at New York and the eight Sections located at Buffalo, Chicago, Cleveland, Detroit, Indianapolis, Minneapolis, New York City and Philadelphia. He has recently been in correspondence with members located in other automotive centers regarding the desirability of forming additional sections in their cities, and it is expected that this plan will result at an early date in the authorization by the Council of the formation of additional sections. This office has recently completed a campaign for additional members for the existing sections of the Society. Letters were written to all the members who did not belong to a Section but were logically eligible for membership in one, and as a result some 200 new Section members were secured.

The Membership Increase Department is also under the jurisdiction of the Sections Secretary, its work being closely related to Sections and membership matters. From fifty to sixty inquiries regarding membership in the Society are received in this department each week and from eighteen to twenty applications for membership. Each application as it comes in, is checked to ascertain whether the applicant has been connected previously with the Society in any way, if all the information which the Council will require for passing upon the application is given and whether the references are to persons who are members of the Society. Should any of this information be lacking a special letter is sent to the applicant. When the application is completed a summary of the experience of the applicant is prepared and sent out to each reference who is asked to supply the information required for the guidance of the Council in determining whether the applicant should be elected a member of the Society and the grade to which he is entitled. All of the applications received each month are listed in the first available issue of THE JOURNAL in accordance with the provisions of the Constitution which require that the name

THE GENERAL OFFICE

of each applicant must be published before any elective action is taken by the Council. The average length of time required for an applicant to be elected to membership is six weeks from the time the application is received. At present, Chairman W. A. Brush of the Membership Committee is carrying on a very effective plan of campaign to secure additional members of a high standing. This plan calls for the cooperation of all of the membership in presenting the advantages of membership in the Society to those who are qualified to join and in sending names of prospective members to the New York office. The results of this campaign which was begun last April have been very gratifying and numerous applications from men who rank high in the industry have been received.

Of major importance in the activities of the Society is the work of the Standards Department. The volume of work handled in this office is growing continuously as the accomplishments of the Standards Committee in the past are increasingly appreciated. This work which is carried on by the Standards Manager and a staff of three assistants consists of preparing the subjects to be considered at the meetings of the various divisions of the Standards Committee and the preparation of the minutes of these meetings, reports on the work of the Divisions for consideration by the Standards Committee at



THE MEMBERS' RECORD DEPARTMENT AND THE FILE ROOM

the Annual and Summer Meetings of the Society. *The Handbook* is edited and revised by the Standards Department and the universally known data sheets originate there. Correspondence and conferences with members of the Society or others in the industry who desire information regarding the standards already in force or who have suggested the desirability of standardizing other subjects forms a large part of the work of this department. Bringing the value of the standards to the attention of the manufacturers and cooperating with them in working out new subjects suitable for standardization is another important function. The office in this connection stands as a medium to create a willingness and desire among the industries to work for the greatest good of all with a resultant actual saving in dollars and cents to manufacturers, purchasers and users of apparatus and equipment employed in the various automotive industries. The Standards Department has charge of exhibits of a general educational nature at the meetings of the Society and important national exhibitions in the automotive field.

The work of preparing the monthly issues of THE JOURNAL and the two volumes of *The Transactions* issued each year falls to the lot of the Publication Department. The larger proportion of the material which appears in THE JOURNAL consists of the papers and discussions presented at the meetings of the Society and the local sections, the presidential addresses delivered at the Annual and Summer Meetings, the speeches made at the dinner which is held in connection with the Annual Meeting and articles of an engineering nature taken from the technical press of this and other countries. In addition there is a certain amount of what can be termed "news" such as reports of the work that is being done each month by the Divisions of the Standards Committee, reports of the meetings of the Council and other Society Committees and items relating to changes in the business connections of the members. Advance printing of papers for presentation at the meetings of the Society and reprinting in separate pamphlet form papers which have appeared in THE JOURNAL is supervised by the Publication Department. Other activities of this department include the preparation of reports such as the pamphlet on the Constitutional Amendments which was issued in the spring, the report of the Fuel Committee which was published in June and the pamphlet giving Data on the Internal-Combustion Engine Fuel Problem which was sent to the members recently. With the increase in the activities of the Society the work of this department has been correspondingly increased, that in connection with the preprinting and reprinting of papers and the issuing of special pamphlets probably being the equivalent of at least three additional issues of THE JOURNAL. *The Transactions* for the first half of 1919 which was delayed by labor conditions over which the Society had no control, constitutes a volume of 824 pages which is 60 per cent larger than either of the semi-annual volumes for the year 1918. At the present time preparation of Part II of the 1919 *Transactions* is well under way and it will be issued in the fall. This volume will probably be somewhat larger than the previous semi-annual volumes, although not as big as the one which was recently issued. The work incident to the advertising appearing in THE JOURNAL is handled by a division of the Publication Department. The correspondence soliciting new advertising contracts originates here and also the work of securing the advertiser's copy, submitting proofs, etc. The value of THE JOURNAL as an advertising medium is being appreciated more as each issue is circulated and the demand for its pages has reflected this feeling. The cuts used in printing the publications of the Society are carefully indexed and stored in files in the Publications Department.

The Office Manager has the general oversight of what might be termed the business phase of the Society work such as the accounting and financial details, the general office and the file, mail and shipping rooms. The financial records of the Society are kept in the Accounting Department in such a manner that costs are readily ascertained for the information and guidance of the Council and the Finance Committee. This department is responsible for the collection of dues and other income and the payment of bills approved by the Treasurer.

In the general office such matters as subscriptions to THE JOURNAL, orders from the members for folders for *The Handbook*, the preparation of membership certificates, the sending out of letters to the newly-elected members who have qualified in accordance with the provisions of the Constitution, the sale of *Handbooks* and other Society publications to non-members and correspondence of a general nature is carried on. The file room is equipped with a very efficient filing system and in it all of the Society correspondence is centralized. Correspondence is drawn from the files only upon presentation of a written requisition to an employe of the file room which is deposited as a charge record eliminating the chance of misplacement and loss of important letters. The mail is received and stamped by the Mail Department. It is carefully routed and delivered by a mail clerk who collects and delivers mail through the offices every half hour. This service promotes efficiency since the delivery of interdepartmental communications is greatly facilitated. The Shipping Department is engaged principally in preparing the material shipped to the members by the Society but it also receives and stores this material and the office supplies. A system of perpetual inventory is in use which eliminates waste and assures prompt filling of requisitions for the office staff or the members.

The Members' Record Department is another of the departments for which the Office Manager is responsible. Its work is of great importance in seeing that THE JOURNAL and the various communications sent out by the office are addressed correctly. In this connection it may not be amiss to call the attention of the members to the fact that unless they notify the office promptly of changes of address it is out of the question for them to receive communications without delay. Whenever a member sends in a notice of a change in his address or company connection it necessitates the changing of two addressograph plates and his card in the three files maintained by this department which are arranged alphabetically according to the member's name, alphabetically according to the name of the company with which he is connected and geographically according to the location of both members and companies. In addition four sets of cards arranged alphabetically by the members' names are maintained in other departments of the office and these, of course, must be changed. All of the eight local sections of the Society receive weekly a list of the changes in address that have been sent into the office. Approximately 200 changes of address are received each week by this department. In this department there are filed approximately 13,000 addressograph plates. These can be divided roughly into four groups, two of approximately 5000 each containing the membership arranged alphabetically according to names and also geographically, one of about 800 of THE JOURNAL subscribers and advertisers and 2500 in what may be termed "special lists" that are used for various purposes.

Like all other well-regulated business establishments the Society headquarters is provided with a private branch exchange telephone switchboard, thus enabling the various members of the staff to communicate with each other and also make and receive outside telephone calls without having to leave their desks. Provision is also made whereby the General Manager can summon any member or members of the staff with whom he desires to hold conferences. From this description of the offices of the Society it is apparent that the officers of the Society and the Council are to be commended for providing ample quarters and proper equipment for the various departments of the staff to conduct the business of the Society in a very efficient manner.

FEDERATED AMERICAN ENGINEERING SOCIETIES

IT has been apparent for many years, with the constant increase in the number of engineering and allied technical societies which carry on their work independently, that some form of comprehensive organization was desirable that could speak for these societies in matters of common concern. For the purpose of soliciting the cooperation of the other national, regional, state and local engineering organizations in the formation of such an organization, an organizing conference was held at Washington, June 3 and 4, under the auspices of a joint conference committee of the four national societies of mechanical, electrical, civil and mining engineers. There were present 140 delegates representing 71 societies having an aggregate membership of over 110,000.

It was a thoroughly representative conference, delegates being present from all sections of the United States. The spirit of the meeting showed a wide-spread and unanimous desire for some form of comprehensive organization that will represent the solidarity of the engineering profession. The Society was represented at this meeting by Past-presidents C. M. Manly and H. E. Coffin, Secretary C. F. Clarkson, Joseph A. Steinmetz and G. W. Coggeshall. Mr. Manly, as the representative of our delegation, has reported to the Council the formation of what will be known as the Federated American Engineering Societies as a result of this conference. The Society has been extended an invitation to join this new organization as a charter member and to appoint delegates for the first meeting of the American Engineering Council, which will be the executive board of the organization. The basis of representation in the Council is the election of one representative for each 1000 members or major fraction thereof. This invitation will be acted upon by the Council at its next meeting in the fall.

The object of the Federated American Engineering Societies as set forth in their constitution is:

> To further the public welfare wherever technical knowledge and engineering experience are involved, and to consider and act upon matters of common concern to the engineering and allied technical professions

The organization is to deal with what are commonly known as welfare and non-technical matters. It is not a social organization nor an organization of individual members. As its title indicates, it is planned to be a federation of societies with whose autonomy and activities there is no interference. It does not create a new technical society nor will it in any sense be a competitor of any existing organization.

The work of the Federated American Engineering Societies will be of a comprehensive character with few fixed lines of activity, its major work depending on conditions as they arise from time to time. It is intended to use its power for the service of the community, state and Nation in affairs wherever engineering experience and technical knowledge are involved. In the conduct of many public matters, which are essentially of an engineering nature, it is vital to the public welfare that engineering and allied technologists should lead. There will be an increasing number of questions arising in which the opinion of these professions will be of fundamental value to the welfare of the Nation, and through the Federated American Engineering Societies it is planned to supply this great public need.

THRILLING EXPERIENCE WITH PARACHUTE

WITHOUT telling their plans beforehand, Sergt. Strong B. Madan took Sergt. Ralph Bottreil up from McCook Field, Dayton, Ohio, in a Le Pere two-seater airplane for an attempt to break the world's record for parachute jumps. Sergeant Bottreil was equipped with the standard Air Service double-pack parachute and after climbing more than an hour, when the airplane had reached 20,600 ft., he started to climb out of the cockpit when the release ring of the parachute accidentally caught in some manner in the fuselage and the parachute opened, dragging him out of the fuselage through the tail assembly of the airplane. Sergeant Bottreil's left arm struck the rudder as he went by, tearing some ligaments and ripping off the sleeve of his fur-lined flying suit. One of the webbing straps of his harness caught over the point of the balance portion of the rudder and tore the rudder entirely off the airplane. The parachute, in blowing through the tail, ripped from the skirt to the vent and broke three shroud lines. This did not, however, seem to increase the velocity of the fall, as the parachute opened and functioned very satisfactorily. Sergeant Bottreil lost considerable blood from his injured arm in the descent, but did not lose consciousness, and at an altitude of about 1000 ft. released the second parachute, which did not open as the fall was so slow owing to the successful functioning of the first parachute. He made a safe landing in a plowed field, and received medical attention in time to prevent any serious results from his thrilling experience.

In the meantime, Sergeant Madan was having an interesting time controlling the airplane with the rudder entirely gone. He found a position of the throttle at which he was able to maintain a straight flight by tipping the airplane slightly to one side with the ailerons. He glided in this condition to about 8000 ft., where he managed to make a wide turn by juggling the throttle and aileron controls, then straightened out and headed for Wilbur Wright Field, where he accomplished a perfect landing. He chose Wilbur Wright Field for his landing place on account of its being much larger than McCook Field.

The altitude at which the jump was made was measured by the same barographs used by Major Schroeder on his altitude flights, and the necessary corrections were applied both for instrumental temperatures and the temperature of the air, giving him a true altitude of 20,600 ft. above sea level for the height at which the jump was made. The indicated altitude was only a few feet higher than this true altitude, on account of the very warm temperature conditions existing near the ground.—Air Service News Letter.

Combustion of Fuels in Internal-Combustion Engines

By C. F. KETTERING[1]

INDIANA SECTION ADDRESS

ALL of us who are connected with the automotive industry have thought for a great many years that we were in a mechanical industry and that we were making machines. It was only at the time when we began to encounter the matter of fuels that we came to realize that the thing which we called a machine was only a piece of apparatus for the effective utilization of chemistry, that the internal-combustion engine upon which all of our industry is founded is purely a piece of chemical apparatus.

The only great cloud on the horizon of the automotive industry today is the question of fuel. Production and production methods have been developed to the point where we can produce any number of automotive devices, and the only real limitation to that is whether we can get fuel to run them with. There are two ways of attacking that problem. One is to increase the fuel supply, and the other is to make the automotive device do what it has been designed to do. If we will consider our machines from the chemical as well as the mechanical point of view, we can do much toward assisting the present situation, in addition to doing what we can to get the fuel people to appreciate what our problem is. Some four or five years ago I first began to talk about this fuel problem. It has only been within the last two years, and especially this last year, that we have got both sides of this tremendous industry to understand that they must correlate each other.

Today, we have refining capacity under construction which will handle twice as much crude oil as we are able to produce, and we have many refineries standing idle because they cannot get crude oil. We have simply been over-optimistic. We have been hoping that we would strike enough new wells each year to take into account the falling off or to meet the increment in the demand for fuel.

The automotive industry has made a very rapid rise in production. The fuel production used to be slightly ahead of the automotive production. It has come along almost parallel, a little above and a little below, but where the automotive production curve shoots up, the fuel curve is shooting down. One of two things will happen. Either the accelerated production curve must bend over, which none of us wants it to do, or we must turn the fuel curve up, which does not necessarily mean a production of more fuel, but it does mean that the demand for fuel per unit must be reduced.

At present, we produce about 1¾ gal. of fuel per day per car. With 2,000,000 or 3,000,000 automobiles and other devices being placed on the market this year, it simply means that the amount which can be allotted to each individual device must be cut down. That is the practical problem that as manufacturers and producers of automotive devices we are facing.

[1]M.S.A.E.—General Motors Research Corporation, Dayton, Ohio.

AVAILABLE FUELS

We have two problems in studying fuel. One is a transition stage, to take care of ourselves in the next fifteen or twenty years, with the utilization of solar energy in transit, so to speak, as a final solution of the problem. In analyzing this, we are always gratified to find that while the future looks dark, and it looks as though we had trouble ahead, yet always there has come an independent scientific investigation that furnished the material with which to solve the ultimate problem.

People used to wonder how they could build fences when they did not have any more rails. Long before the rails ran out, we had wire fences and nobody built a rail fence. The chances are that long before our petroleum supply actually runs out, we will not use it because we will have something better. It takes almost double the amount of alcohol to produce the same effect as a petroleum product such as gasoline.

Our petroleum situation briefly today is that we are getting between 20 and 25 per cent gasoline from the crude oil; 12 per cent goes off as kerosene; about 50 per cent of it is gas and fuel oil, and the rest of it is lubricating oils, paraffins, vaselines, carbon, etc. We have cut down into the kerosene section just as far as we can, and today about 33⅓ per cent of our gasoline comes out of the kerosene section.

We cannot take all of the kerosene over into the gasoline section because 90 per cent of the world is lighted with kerosene lamps. It may come as a surprise to you, but about 95 per cent of the world does not know what electric lights are, and the kerosene demand still exists. Therefore, the price of kerosene will come up practically to the same figure as gasoline.

Half the volume of gas and fuel oil, in our present understanding of the art, is too heavy to handle. As we go down in the gravity of fuels, we introduce several things into an engine. One is the formation of carbon, the other is difficulty of starting, and then the abnormal pounding or knocking in the engine when we try to burn those heavier cuts.

The real fuel problem is what can be done to eliminate the carbon and the knocking in the engine. Then it will not make any difference how far down into the cut we go, because we know well enough today how to vaporize and distribute fuels so that we could handle very much lower stuff than even kerosene.

TWO DISTINCT FUEL PROBLEMS

There are two distinct parts to the fuel problem. One is the question of carburetion and distribution, which is purely external from the engine, and is one of pure physical relationships. The second is the combustion of the fuel after we have it in the cylinder, and the big problem is this one inside of the cylinder. Today we have vaporizing devices of various kinds by which we can get very good distribution to the cylinders. No matter how

good a distributing apparatus we have, we have not yet affected the chemistry of the compound and it will burn in a perfectly normal way, that is the way it wants to burn.

In determining the fuel problem some years ago, we tried to find out what the so-called knock in an engine was; why was there a knock in an engine when it had carbon in it, and why was there none when the carbon was absent? We used to think that it was pre-ignition, igniting ahead of the center, and we used to visualize red-hot particles of carbon in there setting the mixture afire. We have found that as the fuel molecule gets bigger, when it starts to burn, it breaks up and does not burn as a true mixture at all. We burn the hydrogen out of the compound, and precipitate the carbon, which is practically the best heat insulator in the world. Wool ranks first and finely divided carbon is second of the ordinary materials. As long as we hold the critical temperature of combustion below a certain point, the fuel will burn in a perfectly normal way. When we began to study these low-gravity fuels, we naturally applied heat to vaporize them, but the knock was present. After we finally got an idea of what we were trying to do, we thought that we ought to refrigerate the air for a low-gravity fuel, eliminating the distribution problem.

If we took a single-cylinder engine and reduced the temperature of the incoming air to — 10 deg. fahr. we could run that engine on kerosene at 85-lb. compression beautifully. There was no mystery about it after we once knew what happened because the refrigerated air simply prevented the temperature of combustion from going above the point at which that fuel broke down. The only reason that an engine functions better when we take the carbon out is because the cooling system is slightly more active and takes away the peak of that temperature enough to keep the fuel from breaking down. As soon as we get a little deposit of carbon in there, we insulate it and the temperature runs up again. That temperature change is relatively high for a slight change in cooling, because the specific heat of the gases is so low; that is, the amount of heat which is required to raise a volume of gas through a degree is so low that just a little more energy plus or minus means a great raising or lowering of the temperature curve, and a few heat units added to that gas will raise the temperature very many degrees.

If we can do something to keep the temperature of combustion from rising above the point at which the fuel will break down, we will get perfect combustion and engines will run free and without carbon. In fact, we do not care whether we get any carbon deposit or not, because it does not become bothersome except insofar as it influences the combustion.

To carry out that work, we started some years ago to develop an engine indicator which we could put on a cylinder and actually see what took place. We have worked many years on it, not as a problem, but as an adjunct to studying what was happening in the burning of fuel. Since then, we have learned very many things about this particular question of fuel.

Regulating Combustion by Additions to the Fuel

The great problem that we have today is how to regulate the combustion inside the engine cylinder. We could put refrigerated air into an engine and stop the knocking and deposition of carbon with a low-gravity fuel. We have since found that there are many substances which we can add to the fuels in rather small amounts that will effect the same result. There are many mixtures of fuel such as benzol and gasoline, or alcohol and gasoline, marketed under various tradenames, but with alcohol or benzol, it takes approximately 35 or 40 per cent of these to effect a reduction in the rate of combustion. The great difficulty with the lower gravity fuels is that as we increase the temperature, we reach a point where they break down, and the combustion accelerates to perhaps fifty or sixty times as fast as normal combustion, and it is that explosion wave or impact that causes the knock in the engine.

There are a number of substances that can be used. A small quantity of ethyl iodide added to the fuel will transform the engine into an entirely different one. That is quite expensive and entirely outside the range of commercial possibilities, but we can use 2 or 3 per cent of ordinary aniline, which is very much cheaper. If we add 1 per cent of aniline to the fuel of a car that will not climb hills and hammers and knocks, we will have an entirely different automobile. It will not act like the same car at all. Major Schroeder, when he tried to make the great altitude flight, reached 32,000 ft. with his supercharger and could not go any higher. In raising the rarefied air up to the pressure that he wanted, he increased the temperature so that he reached the cracking point of his gasoline. The second time he went up, the boys added 2 or 3 per cent of xylidine, which is an aniline derivative, and he went right through. All we did for him was to change the chemistry of his engine. He did not have the same engine at all in the second case, although he had the same machine, because we changed the chemistry of the fuel he was burning. He went through that 32,000 ft. and could have gone almost indefinitely if he had not run out of oxygen and fallen.

To study this particular problem of what is happening in the engine cylinder, we make an indicator so that it gives a time-pressure diagram instead of the ordinary pressure-volume card. The opening of the intake valve and the compression and ignition points are all clearly shown on such a diagram. After ignition a number of little wiggles appear on some of the cards. We thought that this was due to the inertia of the indicator, but after we had secured thousands of those curves, we found out that every fuel writes its name on the down side of the curve, and the number of wiggles is an absolute measure of the kind of fuel. We have checked that up in a number of ways, and the irregular burning shown is a characteristic of the fuel and has nothing to do with the kind of indicator. No matter if we change the periodicity of that indicator entirely, the wiggles will be approximately the same.

Chemistry of Fuels

The symbol of a typical fuel is CH_4, where each carbon atom can take care of four hydrogen atoms. Alcohol is not as good as a fuel as a hydrocarbon compound. If it was a simple petroleum product the symbol would be C_2H_6 instead of C_2H_5OH. It is possible to produce an alcohol from any hydrocarbon product like gasoline or kerosene by simply substituting OH for one of the hydrogen atoms. In the combustion of these compounds, we unite the hydrogen with oxygen to form water, and the carbon with oxygen to form carbon-dioxide. The oxygen already in the compound is what reduces its heat value so materially. In the alcohol an oxygen atom is already in the combination and the heat value is bound to be lower than if it were not present.

We used to talk about the fact that it was the volatility of fuels which made the great difference in their burning. That has nothing to do with the character-

istics of a fuel. We have taken sulphuric ether, which is a very very volatile fuel with a formula of $C_2H_5OC_2H_5$. The difference between an ether and an alcohol is that instead of there being an OH combination at the end, the oxygen is placed in the middle of it. As a normal compound that O would be out of there. We just simply replace one of the carbon atoms with one of oxygen; otherwise it is a straight hydrocarbon series. A sharp peak on a card taken with this fuel represents the knock, and there is also a very peculiar little cataract wave, a sort of a little double step, that comes further along. The latter is the handwriting of that fuel on the cards which tells us that it is ether. Volatility has absolutely nothing to do with the question and it is that abnormal rise in pressure which is the real fuel problem.

Commercial Pennsylvania gasoline with an end-point about 440 deg. fahr. gives a diagram that is reasonably straight across the top and down on the other side in an engine operating at 60-lb. compression. If the compression is raised to 90 lb. we would begin to bring in all of the diagram characteristics of a knocking fuel. Consequently, as we have been burning lower gravity fuel, we have been reducing the compression pressure, which simply means reducing the peak temperatures. As we run at partial throttle, the compressions are so low that we do not burn the fuel because there really is not enough heat inside the cylinder to vaporize the unvaporized particles, and we have crankcase dilution and all those inherent troubles.

A kerosene from exactly the same Pennsylvania crude oil will give a diagram with a zig-zag combustion wave. The real fuel problem is the abnormal rise in pressure at about the top center, although we have dozens of cards where the peak came at points ranging from the top center to 20 or 25 deg. past the top center as the piston was going down. If there was any pre-ignition, it would be further back, but the combustion starts out perfectly normal. The temperature runs up to the point of decomposition, and then we get an abnormal rise, and the pink or the clink, or whatever it is called.

A fuel oil from exactly the same source gives a card with a series of wiggles or knocks instead of one. Of course, its distillation point was very high.

With commercial benzol an excellent diagram is obtained that comes up, levels off across the top and comes down evenly. We can run the compression up on benzol very high, which means that we can run economically, and it would be a very very good fuel if it was not for two or three things. First, it freezes at about 39 deg. fahr. If the compression is not high enough, benzol is the greatest depositor of a very fine fluffy carbon that we have ever seen. As long as we run the engine on full load in warm weather it is a fine fuel, but if we try to use this fuel in cold weather we are likely to find the fuel tank frozen solid.

During the war we developed a mixture of benzol and benzol with additional hydrogen that is called cyclohexane to help at great altitudes. The important thing about this fuel is that no matter how high the compression rises the characteristic burn will be exactly the same. It levels off at the top of the diagram and we get a full expansion curve. We built and operated a Liberty engine on more than 200-lb. compression. We did not get a knock with that fuel because there was absolutely no decomposition. It was made up of 80 per cent of the cyclo-hexane or hydrogenated benzol and 20 per cent of absolutely carbon free benzol, and had this very interesting characteristic. One of those fuels freezes at 40 deg. fahr. and the other at 39 deg., but a mixture of 80 per cent of one and 20 per cent of the other freezes at —20 deg. fahr. That is not unusual; it is a perfectly normal thing to happen. That was the most extreme kind of a fuel which we could subject to all kinds of abuse, so far as temperature and pressure were concerned.

The diagram was flat at the top because the temperature at which this fuel decomposed was higher than that at which the products of combustion decompose. When any fuel burns, it forms water and carbon-dioxide. If we reached a temperature so high that the water and carbon-dioxide decomposed, then combustion would stop. No matter what the compression was which would run up to a certain temperature, the fuel would simply hang there and burn as it could, and then drop off, so that we never could get above that pressure no matter what we did to our engine.

The interesting thing about California gasoline is that a great proportion of it is of the same composition as the hecter fuel. That is why so many inventors in California have built perfectly wonderful kerosene carbureters and have come East. We put in our Pennsylvania gasoline and they do nothing. They were fine vaporizers, but when we used a fuel in them that would knock, the engines would knock and hammer and pound, and would not pull. The reason is simply the chemical composition of the fuel.

Using carbon-bisulphide as a fuel we get a genuine pre-ignition. This fuel ignites very early and the pressure rises rapidly but it will not knock. Pre-ignition will not necessarily cause a knock, because it may be that the pressures will not rise higher than normal.

Burning Heavy Fuels

We have two problems in burning the heavier fuels, one of vaporization, and then one of combustion; one of mechanical distribution and one of the chemistry of combustion, and it is the latter which is causing all the trouble.

If we take 1 or 2 per cent of aniline and put it into the fuel tank of a car, we completely transform the engine. The great ambition to save fuel means that if we could run our compressions up higher, we would run very much more economically at lower speeds, and at quarter and half throttle, but when we do that, the engine pounds its head off.

It has been our hope to interest the chemical and the fuel people in this problem. We are using fuel now in which we can take a barrel of crude oil, distill off 50 per cent of its entire volume, add about 2 per cent of aniline to it and operate a motor car just as beautifully as we ever did on the old-fashioned gasoline by having some vaporizing device to break it up so that we can get distribution.

In a nutshell, the basic problem of fuels is regulation of the way in which they burn. Our big hope for the increase in fuels today is to cut down into the gas and fuel oil section, which is now 50 per cent of our crude oil. At least 80 per cent of this can be refined the same as kerosene into water white oil, which makes an excellent fuel, if we can eliminate the abnormal rises in pressure.

If we put a little aniline or iodine or some of those other ingredients in a fuel they break down at a lower temperature than the fuel itself, absorb energy and keep the temperature down. We simply put a little material in the fuel that just breaks down shortly before the temperature gets to the point where the fuel itself decomposes, absorbs that energy and does not let the tempera-

ture rise. For example, if we took a mixture of water and alcohol and put it on the stove, we never could raise the temperature of the water while any alcohol remained, because the latter would evaporate and hold the temperature down. This slight addition to the fuel is sufficient to absorb the excess energy when it breaks down and keep the temperature down. A molecule of iodine breaks down at about 1000 or 1100 deg. fahr. and separates into atomic form with the absorption of energy.

Experiments to Show Combustion Phenomena

If we take a glass tube and fill it with a mixture of air and acetylene, which makes a relatively high explosive gas, we can show combustion as it takes place in the engine cylinder. Over the upper end of the large tube, we slip an ordinary test tube. If we let combustion take place normally, the mixture will burn for about half the length of the large tube with a perfectly blue flame. Then it turns white, accelerates very rapidly and bursts the test tube. This experiment does not always work, because the mixtures are very sensitive to temperature, and we sometimes have to try it several times before it works. What I desire to point out is that the combustion runs blue up about half way and then turns white; when it turns white, we always burst the test tube placed over the end.

These tube experiments were carried out a great many years ago by Dr. Harold B. Dixon[2] in England in studying mine explosions, and our indicator diagrams had always showed us that there was an abnormal rise in pressure. Dr. Dickinson, of the Bureau of Standards, in studying Dr. Dixon's work over in England, came to the conclusion that perhaps it was an acceleration of this combustion that caused the trouble, and now we have transferred this over into the glass tube so we could visualize it.

We have put a glass window in an internal-combustion engine cylinder with a spectroscope outside, and when the engine is not knocking, the flame which we saw was always blue. Every time there is a knock the flame is white. If the engine was in a dark room, we could see what appeared to be flashes of lightning every time the engine knocked, and we got the white light through the window.

The test tube is broken by the gas particles, which are traveling at a very much higher velocity, hitting the ends of it. It is not materially different than if we had taken the test tube and hit it with a hammer, and the detonation in an engine is not much different than if we hit the top of the piston with a hammer. It is an intense blow.

This experiment was repeated using the same mixture as before with perhaps a 0.01 per cent of ethyl iodide added to it, which is just enough to absorb any excess pressure and keep the acetylene from breaking down. This gave a very different and slower combustion. The flame was blue all along the tube. If we put more ethyl iodide in, we can slow the combustion down still further. Adding other compounds we can accelerate the combustion or do anything we please.

[[2]Dr. Dixon, who is connected with the University of Manchester, Manchester, England, is engaged at present in fuel research work. This includes the determination of the physical data connected with the explosion of substitute fuels, such as benzine, alcohol and ether, either separately or in combination with each other or with hydrocarbons like pentane, hexane, etc. The data include the ignition point of these gases, the amount of adiabatic compression necessary to fire a mixture of these gases and air by the heat of compression, the spread of the flame through these mixtures from the spark-plug, the conditions under which detonation is produced and the ratio of the specific heats of these gases at varying temperatures.]

What the Chemical Industry Can Do

If the automotive industry could get the chemical industry to increase the coal tar production of the country, enabling aniline to be sold at $2 per gal., and we used 1 per cent, anybody that drives a motor car could afford to use it. If this was the universal practice, we could raise the compression of our engines to 100 lb., which would almost double the efficiency of normal running. We could change the design of our engines, we could do many things, but it will take time.

If we can get these anti-knock chemicals coming on the market, it will help the fuel situation. I am positive that if we interest the chemical talent which is in the oil industry, we can convert some of the products which are already in petroleum into these anti-knock compounds so that all of our fuel can be refined that way. We could then double the efficiency of our engines; we would not care whether we had any carbon in our engines or not. We believe that we are entirely right in saying that we know enough today about this subject so that if we can get the commercial side of it developed and the oil and the chemical people interested, in five years from now, we can guarantee an engine to run indefinitely without any carbon trouble on almost any kind of fuel.

That is really what it is possible to do with the products that we know about today, and I believe that we are making progress, because last year the American Petroleum Institute set aside $1,000,000 to study this subject, and to build laboratories. We have several of the big chemical organizations interested in this. They have never understood the problem, and it is only by such meetings as we have here tonight, coming together and discussing this question and seeing the real difficulty that is before us that we can appreciate the tremendous economic feature of the thing. If fuel with the anti-knock chemicals put in it costs 2 or 3 cents more per gal. it would be more economical at the end of the year because we can save on fuel, we need not use such rich mixtures, and we do not have to tear down our engines as frequently. There is also no carbon trouble, deposition of unburned fuel in the crankcase is almost entirely eliminated, we can run our compressions higher, burn the fuel more thoroughly, and the whole characteristic begins to go in the right direction as soon as we can begin to raise compressions.

The Discussion

R. W. A. Brewer:—Is there any difficulty about the solubility of the compounds you are discussing?

C. F. Kettering:—Absolutely none.

Mr. Brewer:—Do they mix homogeneously without any difficulty?

Mr. Kettering:—Absolutely.

Mr. Brewer:—All of the compounds mix with all of the fuels?

Mr. Kettering:—Yes, there is a long series of these compounds that could be used effectively for anti-knocking purposes, but there is the difficulty of getting some of them into solution. The ones which I mentioned are all easily soluble in any kind of fuel, so that we can dump them in our fuel tank and the shaking around of the automobile will take care of it. If you want to get a surprise, take an engine that is really knocking, go down to the drugstore and get a little bottle of aniline and put in about 1 or 2 per cent and see what a wonderful automobile you will have.

Report on Engine Tests at the Summer Meeting

A SERIES of tests were made on an experimental truck engine at Ottawa Beach, Mich., in connection with the Summer Meeting of the Society. These tests, which were conducted under the supervision of H. L. Horning, secretary and general man-

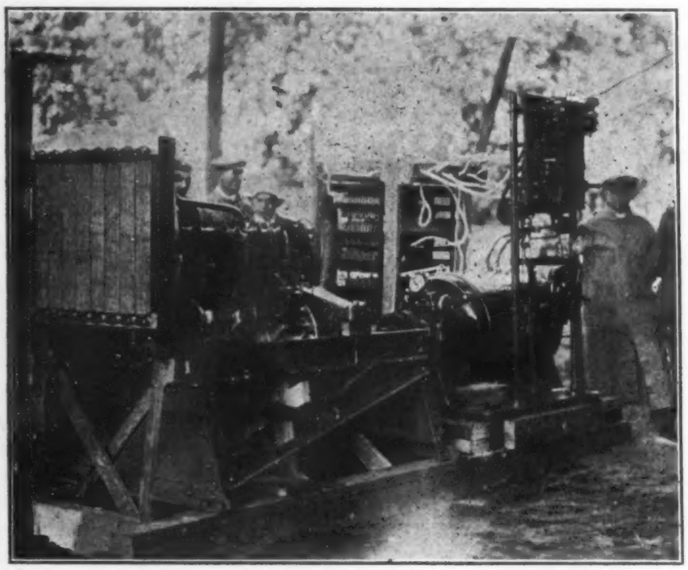


FIG. 1—APPARATUS USED IN THE TESTS

ager, Waukesha Motor Co., Waukesha, Wis., were made to bring out the pitfalls that are likely to be encountered by an engineer in his efforts to apply a hot-spot manifold to an engine. The arrangement of the apparatus employed is shown in Fig. 1.

Four series of tests in all were run. In the first the engine was equipped with the plain manifold shown in Figs. 2 and 3, which is provided with a dam to aid distribution, and in the second a poor design of hot-spot manifold, illustrated in Figs. 4 and 5, was sub-

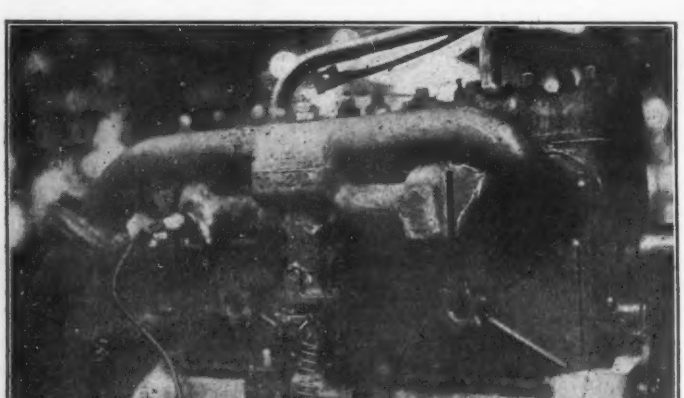


FIG. 2—THE PLAIN MANIFOLD IN POSITION ON THE ENGINE

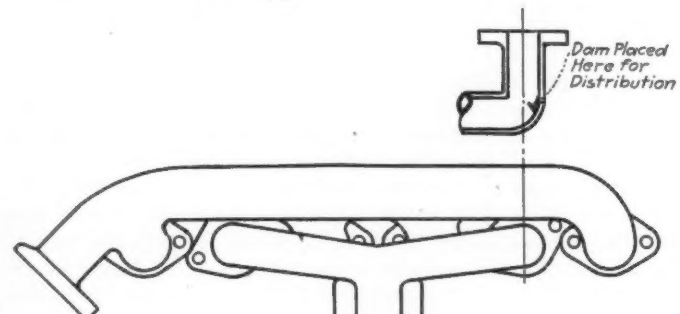


FIG. 3—VIEW OF PLAIN MANIFOLD SHOWING POSITION OF DAM

stituted. This manifold, it is pointed out, should be heated at the points *bb* and *ee*. Horsepower and economy runs were made with both manifolds at speeds of 600, 1000 and 1400 r.p.m. together with fuel consumption runs at each speed with the engine carrying its rated full load and also at half load and quarter load. The third series was to show acceleration and flexibility, while the last was intended to bring out the characteristic changes in the temperature of the exhaust and intake gases.

The engine used was a 4½ by 6¼-in. Waukesha experimental truck type having a displacement of 398 cu. in. and a compression ratio of 3.92 to 1. The valves had a clear opening diameter of 2⅛ in. and a lift of 11/32 in. Force feed lubrication through the crankshaft was employed. The fuel used was gasoline having an end-point of 437 deg. fahr.

The tests were run to bring out the following points of importance:

(1) The decrease in the brake mean effective pressure and horsepower with the hot-spot manifold

(2) The brake economy with the hot-spot manifold at full load and at half load with the same speeds and

FIG. 4—THE HOT-SPOT MANIFOLD

the better performance of the hot-spot over the separate unheated manifolds at quarter load and at all speeds and loadings common in service

(3) The greater flexibility and acceleration of the hot-

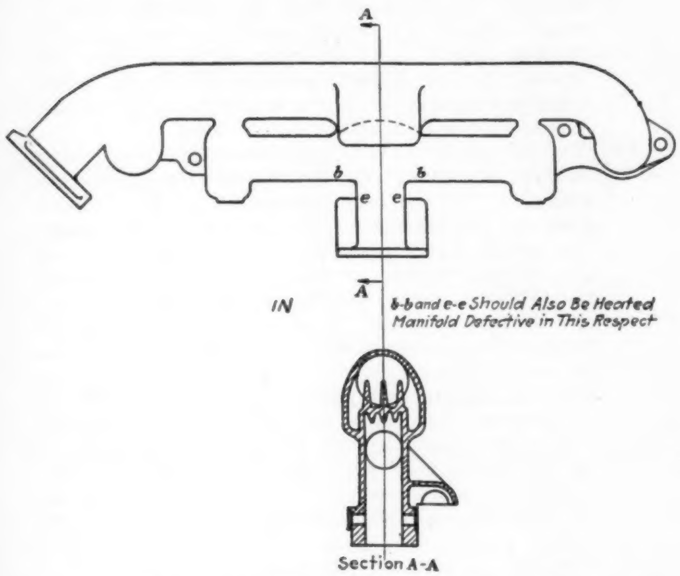


FIG. 5—THE HOT-SPOT MANIFOLD SHOWING POINTS WHERE ADDITIONAL HEAT SHOULD BE SUPPLIED

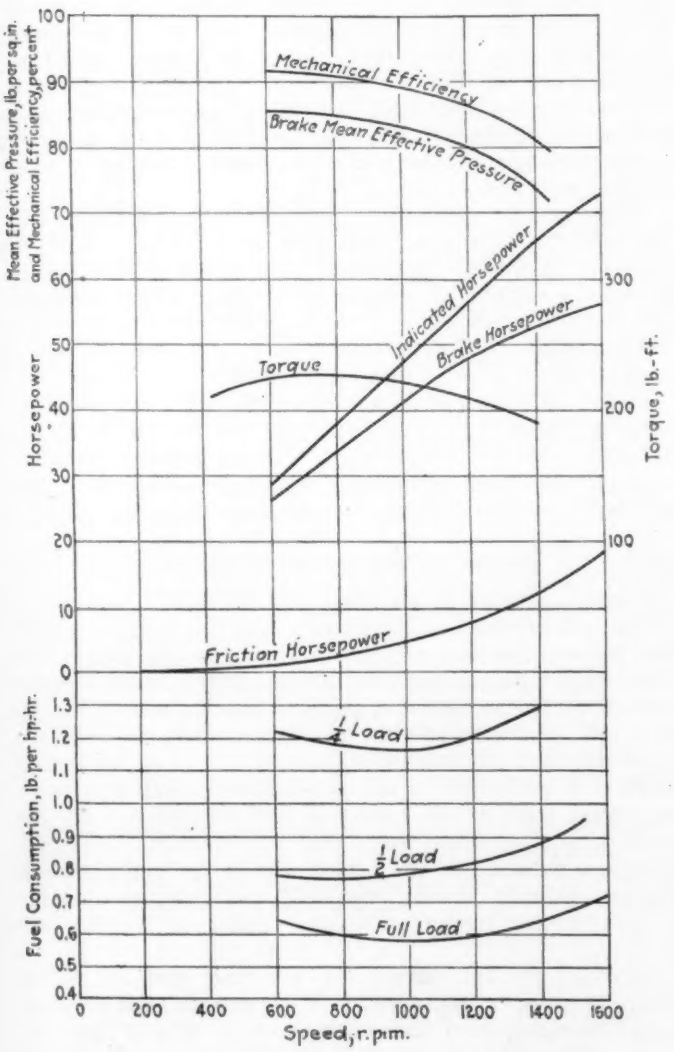


FIG. 6—RESULTS OF TESTS USING THE PLAIN MANIFOLD

spot system which is what the public really wants and most frequently calls power

(4) Exhaust and intake temperature changes with variations in load and speed

Fig. 6 shows curves of horsepower, torque, mean effective pressure, fuel consumption at full load and the mechanical efficiency with plain unheated manifold, while Fig. 7 reproduces the curves of the same factors obtained with the hot-spot manifold.

Fig. 8 shows the fuel consumption figures plotted against the speed for full, half and quarter loads for both manifolds. The change in exhaust and intake temperatures with abrupt changes in load is brought out in Fig. 9. The curves include one of the intake temperature as it varies from idling at 300 r.p.m. to full load at 1000 r.p.m., a curve of the exhaust temperature over the same periods of time as intake temperature, a curve of the intake temperature when running at full load at 1000 r.p.m. and the successive temperature changes of mixture over a period of time when the load is dropped to idling

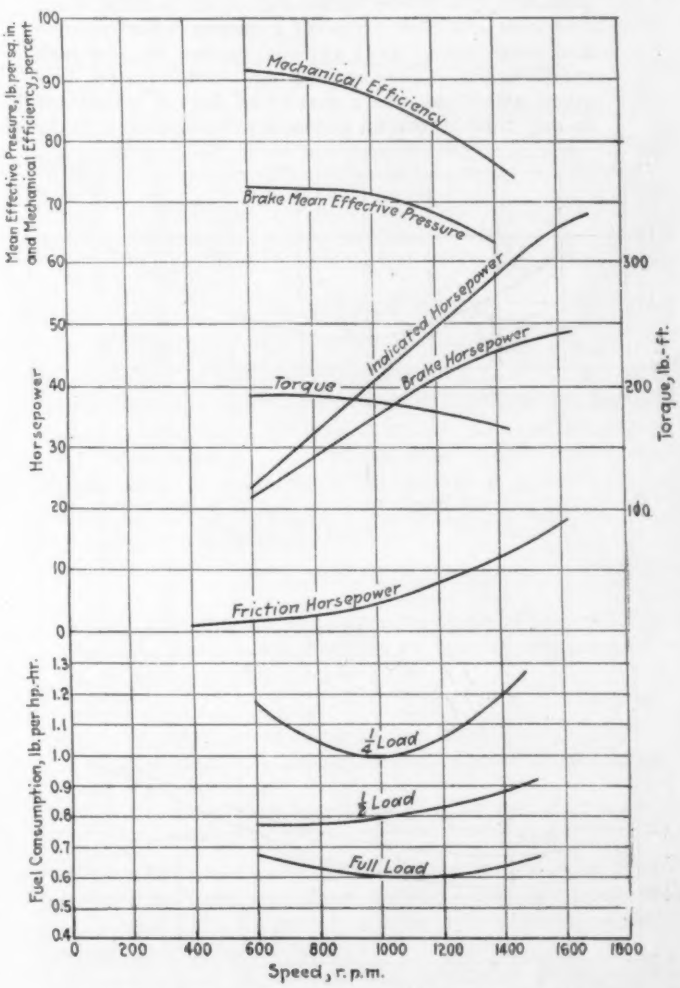


FIG. 7—RESULTS OF TESTS USING THE HOT-SPOT MANIFOLD

at 300 r.p.m. and a curve of the exhaust temperature over the same period and changes of load as the preceding curve.

DECREASE IN BRAKE MEAN EFFECTIVE PRESSURE AND HORSE POWER

After applying a hot-spot manifold some engineers may be disappointed in the loss of horsepower as shown by a

comparison of Figs. 6 and 7. This loss of available horsepower is more apparent than real because of the following facts:

(1) If two engines are applied to two cars which are exactly the same in all details the average user driving these cars in 90 per cent of driving conditions would pronounce the engine with the hot-spot manifold more powerful and satisfactory than the other because of (*a*) better acceleration, (*b*) greater flexibility and (*c*) smoother running

(2) There would be a few conditions such as full load on the hills in summer or maximum speed in which the engine with the plain manifold would be considered the better, but this would represent not more than 5 per cent of the average driving conditions and hence cannot seriously enter into any problem where utility must be uppermost

(3) There is also another very important phase which is a controlling factor in utility. An engine equipped with a plain manifold and run for any length of time would suffer from loss of compression due to excessive oiling and fuel going by the pistons. The valves would carbonize quickly, warp and leak and need frequent grinding. The pistons and rings would wear rapidly, carbon up and leak compression. The spark-plugs would need frequent attention. As a matter of fact it would not be any time before an engine equipped with a plain manifold would be in such bad condition that it would not give the results shown in Fig. 7, and its running condition would grow worse rapidly. On top of this the diluted condition of the oil in the crankcase would develop a metal to metal contact in bearings with resultant rapid wear

(4) The difference in brake and service conditions must be kept in mind. On the brake the horsepower available is at its best because of the fixed speed, load and temperatures. In service rapidly changing speeds make severe changes in the density of the charge because of vaporization and distribution difficulties plus the variable flow characteristics of fuel and air. It is these problems which hot-spot manifolding solves and hence gives the desired performance. The public want a thing they incorrectly call power. Usually it is really acceleration they want; very often it is torque, but except at extreme speeds the public's understanding of power does not coincide with that of the engineer. Service conditions demand acceleration and deceleration, heavy pulls up grades at moderate speeds and under these conditions the hot-spot manifold or any system that vaporizes the fuel makes power available to the user instantly

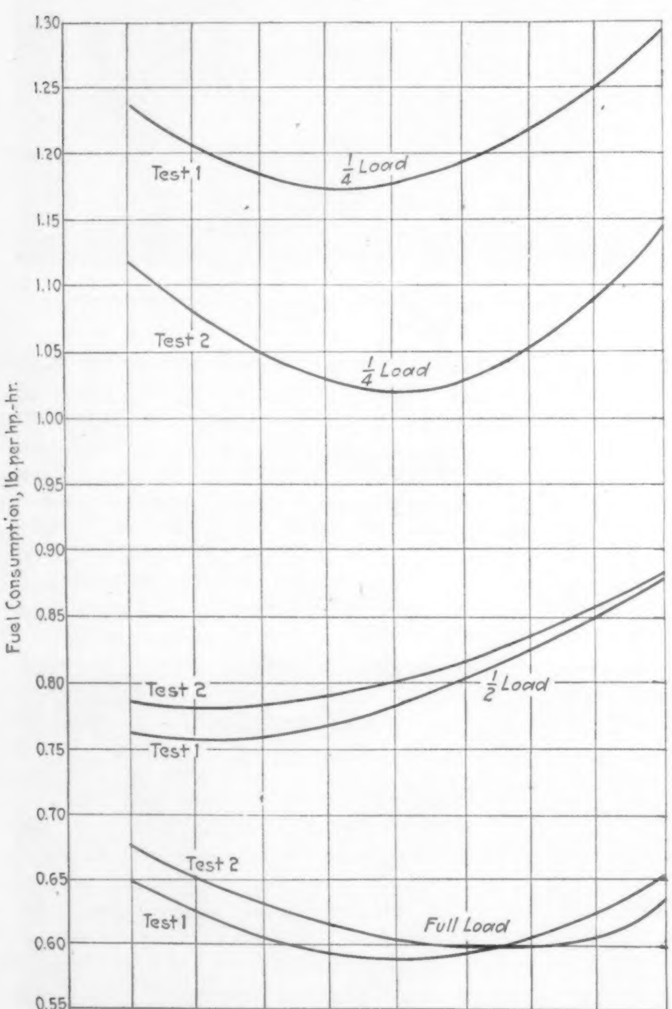


FIG. 8—CURVES OF FUEL CONSUMPTION AT VARIOUS SPEEDS OBTAINED FROM THE TESTS

BRAKE ECONOMY WITH THE HOT-SPOT MANIFOLD

Smoothness of operation is the most desirable and noticeable effect of vaporization and distribution of the mixture. The engine as equipped in the first series of tests would have poor distribution and would be rough. On this account one cylinder might do as much as 40 per cent more work than its neighbor. The improvement in the operation of hot-spot over plain manifold engines is due more to the improvement in distribution than the better thermal efficiency derived from burning a more perfect mixture.

The engineer must keep in mind that notwithstanding the fact that the plain manifold shows greater specific economy at full and half loads on the test block than the hot-spot manifold; in service with rapidly changing loads and with the difficulties of vaporization, distribution and fuel, if economy of operation is of importance, the choice is entirely in favor of the hot-spot type.

Below half load, even on the brake, the best performance as shown is with the hot-spot and in service this is accented. In motor cars and trucks the average performance is under half load; hence, herein lies the great value of the hot spot as a means to securing increased mileage.

ACCELERATION AND FLEXIBILITY

A trial to show acceleration and flexibility proves the great improvement of the heated over the cold manifold. The acceleration characteristics shown in the rough test given were identical with the accurately measured acceleration reported in the tests made by the Bureau of Standards and presented at this meeting. When the mixture is set lean and the engine is running idle or at low speed there is a hesitation in the acceleration which reaches a maximum with a cold manifold and decreases with the improvement in distribution and vaporization. Acceleration is a function of the heat available for vaporization, the gas velocity in the manifold and mixture density in the cylinder immediately after changing the throttle position.

Acceleration and flexibility are the characteristics greatly desired by the public. If an engine fails to show these characteristics the average man calls it lack of power. This is only partly true. The power ability is

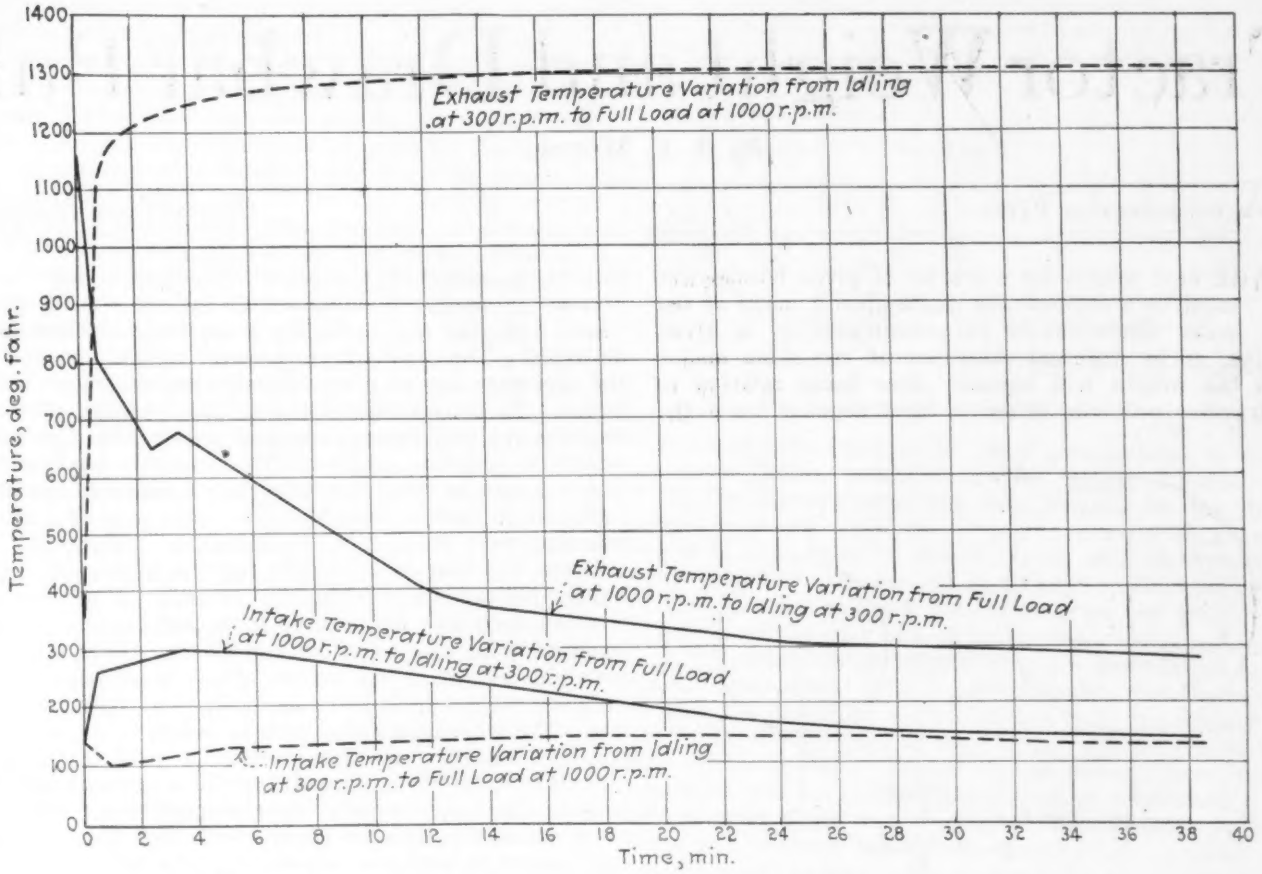


FIG. 9—CHANGES IN INTAKE AND EXHAUST TEMPERATURES RESULTING FROM VARIATIONS IN LOAD

not instantly available although the engine might be capable of delivering good power. The hesitation of an engine to respond quickly to demands of service constitutes a real cause of dissatisfaction to the public and a real loss in economy. The last statement gives the real reason why service improvement in economy is far greater than is apparent from the brake economies.

The engineers must again weigh the actual working conditions against the brake performance. The following conclusions are to be derived from a study of Fig. 9.

(1) The hot-spot manifold must be designed so as to have as thin a section as possible at the hot spot and made of highly conducting material if the time of warming up from idle or cold running is to be a minimum and the intake gases are to respond quickly in temperatures to the change in the demand on the engine for power
(2) With a thick section of metal of low conductivity at the hot spot the mixture is slow to warm up from cold or idle running and fast to warm up from a high speed and high-load performance
(3) The fourth series of tests is as severe as any set of conditions to be found in service with the exception of starting
(4) The time element in average service conditions will not be as severe as in the fourth series of tests and hence the temperature of the mixture will tend to keep more nearly constant

In the hot-spot system it is obvious from an examination of Fig. 9 that where an engine has been running under a good load in service and is required to stop for 15 min. the reserve heat is manifest by the mixture temperature and is valuable as an acceleration help. Likewise the slowness in heating while starting cold is an unavoidable limitation. The engineer must, therefore, recognize that in a brake test without thermocouples or an accelerometer it is difficult to detect the much better performance of the hot-spot manifold. The driver will, however, recognize this difference immediately in its favor on the basis of the availability of power.

GENERAL CONCLUSIONS

There are five general requirements which constitute a full measure of satisfaction in the operation of an engine in service. These are

(1) Power and torque
(2) Flexibility and acceleration
(3) Low-speed pulling without load
(4) Fuel consumption
(5) Freedom from crankcase dilution and its resultant bad effects

To make these instantly available the hot-spot manifold accomplishes the results in service with an apparent loss but a real gain in power, torque and economy over that indicated by a brake test.

The effect of turbulence was shown by attaining fairly good results at low compression and without knocking. The magneto could be advanced so that the engine would slow down without detonation effects, yet with a good mean effective pressure and a low fuel consumption.

The tests were made under the difficulty of being in the open, the wind affecting the gasoline weighing beams, and were not unusual, as under better conditions of control the engine tested has shown a mean effective pressure of 98 lb. and a fuel consumption of 0.535 lb. per hp.-hr.

Tractor Weight and Drawbar Pull

By A. F. Moyer[1]

Minneapolis Section Paper *Illustrated with* Diagrams

The best weight for a tractor of given horsepower must be a compromise based upon a mean of the many conditions to be encountered by a given machine, or by different machines of the same model. While the weight will logically bear some relation to the drawbar pull, the latter in turn depends upon the tractor speed. Having established the total weight and speed, the next item for consideration is the weight distribution.

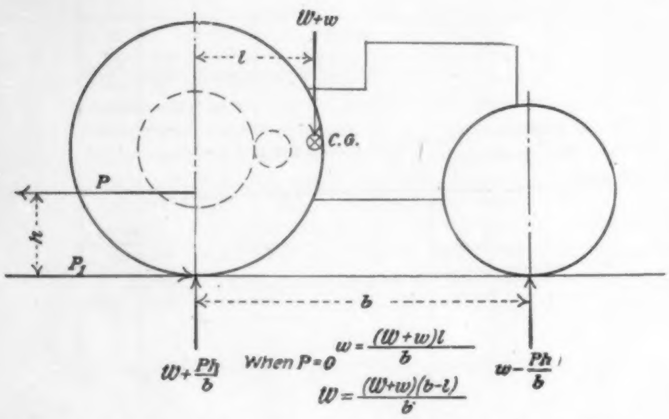


Fig. 1—Tractor Operating on Comparatively Firm Ground

Slow-moving tractors will always involve greater weight, both for the strength of parts and for obtaining the necessary traction to develop the larger drawbar pull. High speeds, on the other hand, permit light-weight construction, with several advantages as well as some limitations. It seems almost beyond question that tractor implements will soon be adapted to higher speeds, so that the limitations of draft-horse speeds will no longer hamper the tractor as a branch of the automotive industry. Good plowing at 3 to 4 m.p.h. ought soon to become possible without sacrificing efficiency. Taking the speed at or near the highest at which good work can be done efficiently the drawbar pull is readily determined from the drawbar horsepower, or vice versa. The ratio of drawbar pull to the total tractor weight is the next consideration. In a few exceptional cases this ratio has shown on test a value as high as 100 per cent, but this probably will be nearer 70 per cent for average conditions with rear-wheel-drive machines, depending upon wheel equipment and weight distribution. For crawler and four-wheel-drive types with proper weight distribution, a higher value is obtainable.

Having deduced the desirable tractor weight, the skill of the designer is called upon to the utmost, not only to keep within the desirable limit, but at the same time to make the best distribution of the weight at his disposal. Ample wheel diameter should be considered of importance as long as the transmission weight can be kept within bounds. Cost is at direct variance with this consideration, except that drive-wheel efficiency will be increased by larger diameters and that this permits the use of a smaller engine for the same drawbar horsepower delivered. The elimination of excess weight also reduces the necessary engine power by reducing the wheel rolling losses. To deliver the power to the drawbar efficiently requires the best proportioning of parts, with high-grade materials properly applied. The superior performance and economy of operation with such a machine should be sufficient to justify the added cost, over that of a design executed with cheapness of production uppermost.

Given the best total weight for the high-speed light-weight tractor, the distribution between the driving and steering members becomes of great importance. For a machine with two rear driving-wheels, there must be sufficient weight in the rear to obtain good traction and sufficient weight in front to maintain good steering qualities. The wheelbase being usually short, there is a comparatively narrow margin between a good distribution of weight when normally working and a state of unstable equilibrium under certain adverse conditions. Although there appears to be some controversy over the contributing factors to unstable equilibrium, the different conditions cited lend themselves to analysis by considering the tractor as a unit of which the drive-wheels constitute a resistant, though moving member, and subject to the application of external forces. The first condition is when the tractor is operating on a comparatively firm surface and exerting a pull P at the drawbar, which is h inches above the ground. In Fig. 1, the active force P, of which P_1 is the equal and opposite reaction, is the tangential effort of the tires and rear faces of the lugs against the soil, h inches below the drawbar. The product Ph therefore represents a couple or torque tending to lift the front wheels of the tractor so that, if b represents the wheelbase, the value of Ph/b represents the weight in pounds lifted from the front wheels and transferred to the rear wheels. Where the wheelbase is short,

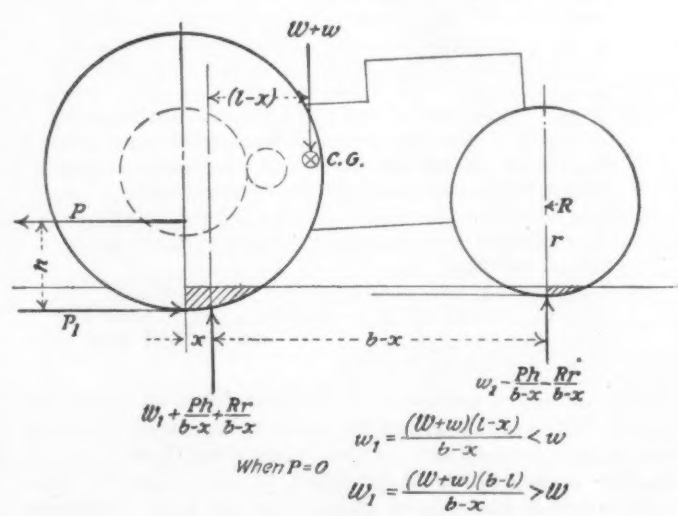


Fig. 2—Tractor in Soft Ground

[1]M. S. A. E.—Engineer, Toro Motor Co., Minneapolis.

this shows that more weight should be carried in front than when the wheelbase is long.

The above analysis applies perfectly when the machine is on firm ground, but a modification arises immediately upon entering soft soil, as shown in Fig. 2. In the *Transactions*,[2] I proposed a method of determining the weight-carrying capacity of a wheel from the cubic inches of soil displaced by that part of the tire from the center forward which is in contact with the soil. This displacement has a buoyancy similar to that from hydrostatic pressure and the center of mean supporting pressure is forward of the center of the wheel. The result is a virtual shortening of the wheelbase by a distance subtracted from the rear, thus further increasing the weight carried at this point and decreasing that carried in front. This action takes place in soft soil whether there is a drawbar pull or not, and the two acting in combination on an up-grade will often lift the front wheels of a tractor, as indicated in Fig. 3. In this connection it will be noted that a low center of gravity has an advantage on grades.

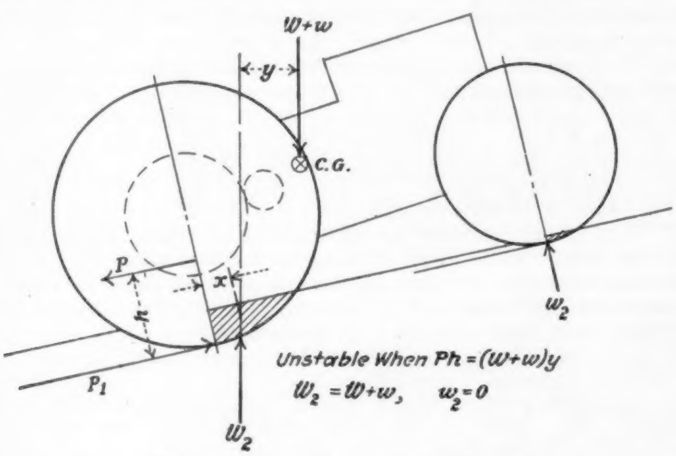


FIG. 3—TRACTOR ASCENDING A GRADE

A third and, perhaps, the most severe condition arises when the drive-wheels are deeply mired, as shown in Fig. 4, and an attempt is made to drive the machine ahead. So long as there is sufficient progress ahead to clear the rising tire lugs on the rear, this is a bad condition of the preceding case. But, when forward movement ceases and the wheel begins to dig a pocket, traction is obtained by the lugs on the rear as well as by those on the front, setting up a braking effect of the rear wheels on a fixed center which is certain to lift the front if given sufficient depth and power. If, under this condition, an obstruction is placed under the lugs at the front of the wheel, a straight lift is obtained there which, if accompanied by holding down at the rear due to lug traction, can produce but one result: the machine will stop only with the first substantial obstruction to a backward somersault. If, as a precaution, the machine is designed so that the full torque transmitted from the engine to the rear wheels would seem unable to accomplish this disastrous result, there is still danger that the flywheel energy from a speeded engine with quickly-engaged clutch might provide the required torque. For this reason adequate means should always be provided against turning turtle, and the drivers should be warned to back out of a bad hole.

A careful analysis should be made of the conditions

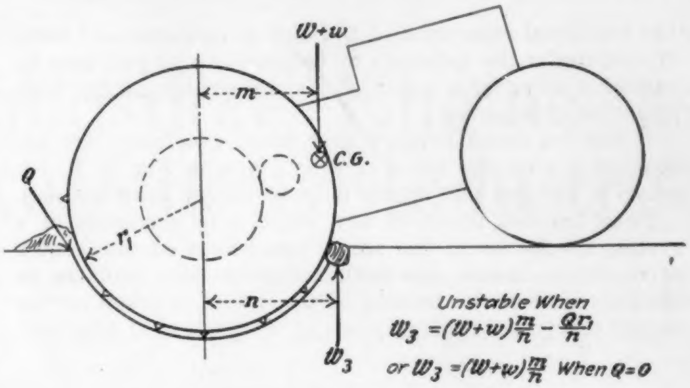


FIG. 4—DRIVE WHEELS OF TRACTOR MIRED

obtainable with any type of wheel arrangement or drive members before establishing the weight distribution. With the crawler type, the dead weight on the drive members should have the center of gravity at a point ahead of the center of tracks, or be applied through a support as near the ground as possible so that the effect of the drawbar pull will not be to throw the weight excessively on the rear end of the tracks.

A four-wheel-drive tractor requires a modification of the above analysis. Fig. 1 applies, except that the center of gravity should be shifted ahead until the weight on the front drive-wheels at least equals the weight on the rear when pulling. Fig. 2 should have a front-wheel condition similar to the rear, including a distance x by which the support can be shifted ahead of the axle in soft soil without materially altering the equality of weight when pulling. Fig. 3 would be an entirely safe condition for four-wheel drive, because of the large value of y with the center of gravity further forward. Fig. 4 becomes an impossible condition with a four-wheel drive, because both front and rear wheels would "dig in" and avoid the angular displacement, and because the center of gravity is far enough forward to prevent turning over. A four-wheel drive with center differential, moreover, could never lift the front wheels because at that instant all traction would be lost.

In conclusion, it is apparent that, while careful engineering will make the light-weight tractor of conventional type stable under most conditions, there is a possibility that any future trend toward lighter machines will open up the field to other types.

THE DISCUSSION

The discussion offered, following the presentation of this paper, was to the effect that when the drawbar height above the ground is not considered, but the torque on the final drive gears is taken instead, and when the product of the drawbar pull into the distance of the drawbar below the rear axle is deducted from this torque, the result divided by the wheelbase gives a weight lifted from the front wheels which seems to agree closely with experimental tests. The analysis shown in Fig. 1, however, shows a wide discrepancy from actual test data.

In reply the author wished to amend the use of the expressions "comparatively firm surface" and "firm ground" to signify an ideal surface with perfect traction but without rolling resistance. Such a surface is never obtained in practice and therefore Fig. 1 does not apply. Fig. 2 will apply to all actual cases if it is understood that the displacement x of the virtual support ahead of the rear axle is sufficient to account for all of the drive-wheel losses. In some instances where a heavy pull is exerted with sharp lugs on tough sod, it is possible that

[2]See *S. A. E. Transactions*, vol. XIII, part 1, p. 405.

the frictional resistance of the lugs to entrance and withdrawal under the influence of tangential rim pull may be sufficient to equal a value of x considerably larger than might be anticipated.

It can be noted further that when the losses are accounted for by the value of x as given in Fig. 2, P_1 becomes a net rim pull which is equal to the drawbar pull.

Since the net result of any solution by moments of a system of forces is the same, regardless of the center of moments chosen, the author regards this problem as simplified when the bottom of the wheel is taken as the center of computation in place of the center of the axle. In this case the moment of P_1 becomes zero and can be neglected so that an equation can be at once written which separates drawbar pull from wheel losses in their true sense, and renders the determination of drive-wheel torque unnecessary. While the author's equation expresses drawbar pull as lifting the front wheels and the other analysis expresses it as holding them down, it is always true that this so-called holding-down torque is less than the lifting torque applied to produce the drawbar pull. The author has, therefore, expressed net values which are the mathematical equivalent of the other solution.

UNPRECEDENTED ROAD BUILDING PROGRAM

THE unprecedented stimulus given highway construction in the United States in the four years that have passed since the Federal Government entered upon its policy of aiding road improvement, is shown by the fact that road operations under the Federal-aid road act thus far initiated aggregate in length nine times the distance from New York to San Francisco, according to Thomas H. MacDonald, chief of the Bureau of Public Roads, Department of Agriculture. The Federal Government's share in this stupendous undertaking is greater than the cost of the Panama Canal. The participation of the National Government in highway improvement marked a departure from a policy which had been followed for nearly a century.

The Federal Government's present program of highway improvement is the result of two acts; the Federal-aid road act signed by the President July 11, 1916, and provisions in the Post-Office appropriation bill for 1920, signed Feb. 28, 1919, containing an amendment to the original Federal-aid road act. The original appropriation of $75,000,000 was made available for rural post roads in installments at the rate of $5,000,000 for the fiscal year ended June 30, 1917; $10,000,000 for the fiscal year 1918; $15,000,000 for the year 1919; $20,000,000 for the year 1920; and $25,000,000 for the fiscal year ending June 30, 1921. Ten million dollars for forest roads was made available at the yearly rate of $1,000,000 after July 1, 1916. The apportionment of the post-road appropriations of the States after deducting the administrative fund, which must not exceed 3 per cent, is based upon area, population and mileage of rural delivery and star routes in each State. Each of these factors has a weight of one-third.

The Post-Office appropriation bill carried an additional appropriation of $200,000,000 for the construction of Federal-aid roads and $9,000,000 additional for the construction and maintenance of roads and trails in the national forests.

All of these Federal funds may be expended only for construction and must not exceed 50 per cent of the value of the roads. In other words, the States either directly or through county or other Government units, are required to bear something more than half of the total cost of their road improvement.

The Federal-aid act requires that road projects for Federal aid be initiated by the States and be approved by the Secretary of Agriculture. Up to June 30, 1920, 2985 projects involving a total of 29,319 miles of road had received official approval. The preliminary estimate of the cost of these projects is approximately $384,900,000, of which about $163,841,000 will be available as Federal aid. On the same date 2116 projects representing approximately 15,944 miles had either been completed or were under construction. The estimated total cost of these projects in various stages of construction and completed, is $200,000,000. The total cost of Federal-aid work approved by the secretary in the nineteen months prior to July 1, 1920, which is approximately $330,000,000, exceeded by $63,000,000 the cost of all road and bridge work done by States and counties in this country in 1915. The value of the work completed in that period amounted to $60,000,000, a rate of construction equalling that of the Panama Canal.

In 1915 the total expenditure for roads and bridges by all the States and local governments was $267,000,000, while this year the estimated funds available for main road construction are nearly three times that amount, or $633,000,000. In all, Federal funds to the amount of $266,750,000 have been apportioned among forty-eight States.

Second only in importance to the size of the present road-building program is the excellence of the character of the roads being built. Sixty per cent of the total allotment of Federal funds which has been approved to date will be spent for roads of such durable types as bituminous concrete, Portland cement concrete and vitrified brick. These roads when built will increase by 7600 miles the total of 14,400 miles of roads of this class which existed in the United States before the Federal-aid road law was passed.

OPERATION AND CARE OF VEHICLE-TYPE BATTERIES

THE Bureau of Standards has just issued a very comprehensive booklet entitled Operation and Care of Vehicle-type Batteries. This booklet is intended primarily for the instruction of those responsible for the operation and maintenance of electric storage batteries used on automotive equipment. It is, however, very instructive to anyone interested in the construction of modern electric storage batteries and gives considerable information of an engineering character.

The first quarter of the book is devoted to a semi-technical description of the lead-acid and nickel-iron storage batteries which are the two general types of practical importance. The various plates and cells are illustrated, together with a description of the jars and connectors. A large portion of the booklet is given over to detailed instructions on the preparation of electrolytes for storage batteries and methods of charging. A very valuable and comprehensive set of illustrations with instructions outlines the dismantling and assembly of the lead-acid type of battery and the proper methods of cleaning it. In the appendix, several suggested forms for use by those in charge of battery maintenance are given, and the booklet ends with a very complete glossary of those words peculiar to the liquid storage battery.

Copies of this booklet can be obtained from the Superintendent of Documents, Government Printing Office, Washington, at the rate of 30 cents each.

The Internal-Combustion Engine as Developed by the Automotive Industry[1]

By J. G. VINCENT[2] *Illustrated with* PHOTOGRAPHS AND DRAWINGS

THE origin of all energy used by mankind in the development of light, heat or power is the sun. For countless ages energy from this source has been stored in one way or another. One of man's first attempts to convert this energy into mechanical power was in the nature of windmills which were operated by the changing air currents brought about by the constantly varying temperatures of our atmosphere. Likewise hydraulic power was converted into mechanical energy through the use of water-wheels, thus being but another manifestation of the sun's energy which in this instance by evaporation had raised water from one level and deposited it on a higher level, the energy flowing down again in a form useful to man.

It was not until nearly the end of the eighteenth century that the energy stored in the form of gaseous, liquid and solid fuels became available as a source of power. The steam engine invented by Watt in 1769 represented the first practical means of converting such energy into mechanical power. Some 107 years later Otto constructed the first practical four-cycle internal-combustion engine. We therefore have at present four distinct types of prime movers, the windmill, the water-wheel and water turbine, the steam engine and steam turbine and the internal-combustion engine. The windmill is rapidly becoming obsolete since it is not available as a continuous source of power and the initial investment is higher than that of other prime movers of a similar capacity. Hydraulic power is still far from being utilized to the fullest extent and its continual development is being universally encouraged as the most important means of conserving our fuel resources. Transcontinental trains are today being run several hundred miles of route by electricity generated from the harnessing of Rocky Mountain waterfalls and the future will doubtless see similar projects carried out on a far greater scale. However, it does not seem probable that hydraulic power will ever exert a serious influence in the automotive field unless there should be some startling development in the storage battery art which would cause the electric motor to challenge the position held by the internal-combustion engine in the automotive field.

We thus find that, at present, real development is limited to the three distinct types of prime movers represented by hydraulic, steam and internal-combustion engines. The steam engine today dominates in the field of stationary power development and in the rail transportation field the steam locomotive is still supreme. The internal-combustion engine has created a new field of transportation power development, resulting in a power unit that is not confined to rails but capable of traversing roads, fields, water and the air when adapted to the automobile, truck, tractor, motor boat or airplane as the case may be. The internal-combustion engine has also created for itself a new field in supplying the demand for small stationary power units for generating electricity or furnishing power.

The internal-combustion engine of the now almost universally used four-cycle type owes its rapid development primarily to the automobile. Marine engines, especially of the two-cycle type, were widely used while the automobile was still a curiosity, but it was not until the advent of the popular demand for automobiles that serious engineering attention was concentrated on developing and refining the four-cycle engine. I will not attempt to describe in detail the various steps in this development process but merely cover this phase generally, leaving the major part of the discussion available for considering the essential details as represented by modern practice.

Before starting to trace the development of the automobile engine of the internal-combustion type, it will be well to state that the principle of the four-cycle engine has not been changed one iota since its original conception; what we have accomplished has been through a process of intensive development and refinement of detail design. The net result is that the engine of today in contrast to its prototype is extremely reliable, very light and compact, covers a wide range of useful speeds and loads, operates quietly and without attention over long periods, and is capable of a higher thermal efficiency even in small units than the largest steam powerplant.

I believe that the best method of tracing internal-combustion engine development lies in considering each important element of the engine and examining its gradual evolution. I have divided the subject into the following twelve divisions which I will take up in detail successively:

(1) Cylinder arrangement
(2) Valve arrangement
(3) Pistons and rings
(4) Crankshafts
(5) Connecting-rods
(6) Flywheel
(7) Crankcase
(8) Lubrication system
(9) Carburetion system
(10) Ignition system
(11) Starting system
(12) Cooling system

I propose to cover briefly the historical aspect of the various stages in the development of each of these groups and then consider the special characteristics required of each element in the passenger-car, commercial-vehicle, tractor, aircraft and watercraft branches of the automotive industry.

CYLINDER ARRANGEMENT

The single-cylinder horizontal engine was favored by the early American designers in contrast to the single or two-cylinder vertical type of the European engineers.

[1]Paper, substantially in full, presented to the engineering students of Yale University, New Haven, Conn., May 7, 1920.
[2]M. S. A. E.—Vice-president in charge of engineering, Packard Motor Car Co., Detroit.

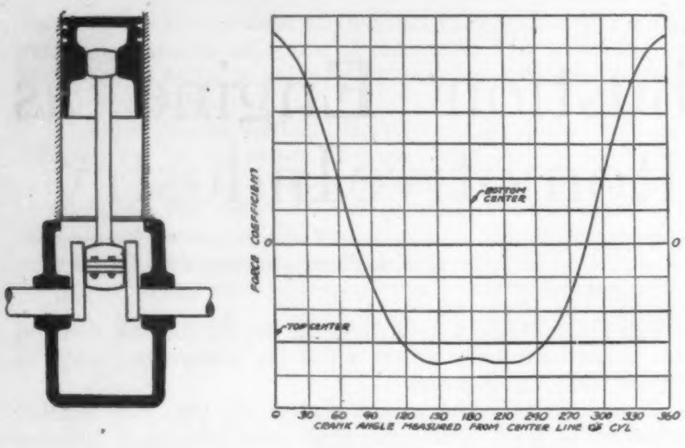


FIG. 1—UNBALANCED CONDITION PRESENT IN A SINGLE-CYLINDER ENGINE

The disadvantages of the single-cylinder engine were soon appreciated, the heavy reciprocating parts of the large cylinder prohibited a high engine speed so that the power impulses were necessarily not only far apart but extremely violent. Furthermore, it was impossible to overcome the heavy forces resulting from the constantly changing velocities of the reciprocating parts by any system of balancing. Later, for convenience, I refer to these forces as inertia forces. This unbalanced condition is shown graphically in Fig. 1. As the comfort of the passengers was a prime consideration, the next step was the two-cylinder horizontal-opposed engine. From the standpoint of mechanical balance this engine was greatly superior to its predecessor, as will appear by reference to Fig. 2 where the inertia forces due to the reciprocating parts have been graphically shown, the forces acting on one piston being at all times offset by an equal and opposite force acting on the other piston. However, there is still a couple about the center of the engine which interferes with perfectly smooth running. This couple is shown in Fig. 3 and is the result of the offset relationship between the two cylinders. The individual power impulses at the lower speeds were still uncomfortably apparent to the passenger and in the matter of flexibility there was much to be desired. Lubrication and carburetion problems also were responsible for abandoning the two-cylinder horizontal engine for

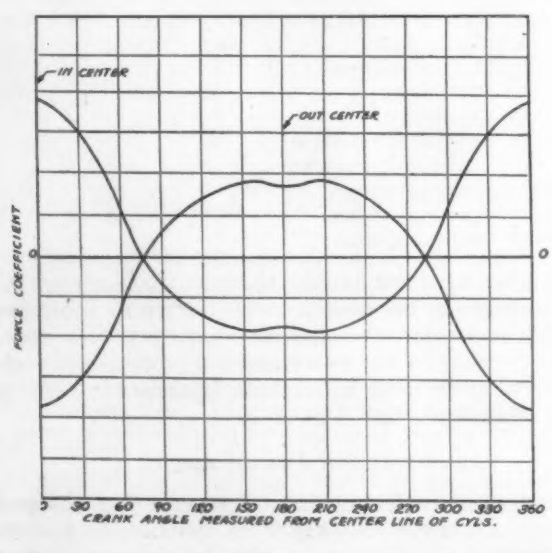


FIG. 2—BALANCE OF INERTIA FORCES IN A TWO-CYLINDER ENGINE

the four-cylinder type. Furthermore, with a fixed chassis width the two-cylinder opposed engine could not meet the demand for more power and consequently larger engines.

A three-cylinder engine was featured in two-cycle engines and in at least one case in a four-cycle engine, but it was soon realized that the four-cylinder vertical four-cycle engine had many advantages, the chief of which can be summarized as follows:

The impulse frequency is fairly satisfactory, there being two explosions per revolution. The engine is compact and accessible and can be built in units giving rather high horsepower, the crankshaft is sturdy and easily manufactured and the problem of distributing the carburetted mixture is particularly easy to solve. This is due to the symmetrical arrangement of the inlet manifold that is possible owing to the absence of overlapping suction impulses. The flexibility of the four-cylinder engine of moderate horsepower is not very great and its useful power range can be considered to lie between 400 and 1800 r.p.m. With gear ratios commonly employed, this would correspond to a car speed of from about 13 to 60

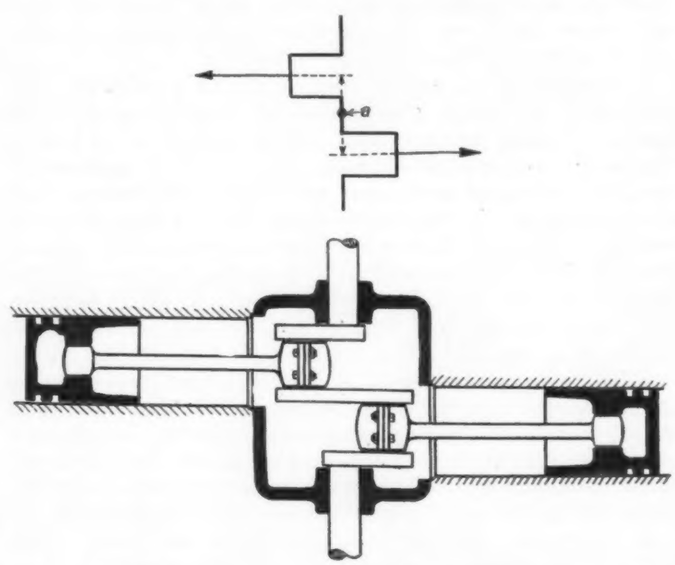


FIG. 3—THE "COUPLE" IN A TWO-CYLINDER ENGINE WHICH INTERFERES WITH SMOOTH RUNNING

m.p.h. For low speed, therefore, it was necessary to shift gears frequently and if the gear ratio was lowered to bring the range of useful speed from, say, 10 to 45 m.p.h., the underlying fault of the four-cylinder engine became at once apparent at fairly moderate speeds. This can best be understood by reference to Fig. 4, which shows a condition common to all four-cylinder engines with cranks at 180 deg. When one pair of pistons is in mid-stroke position, the other pair occupies a lower position, the extent of this difference depending upon the angularity of the connecting-rod. Since the inertia forces acting on the pistons vary with different positions in the stroke, it is clear that the forces acting on the pair of pistons in mid-stroke are not equal and opposite to those acting on the other pair. The diagram of the inertia forces in a four-cylinder engine shown in Fig. 5 clearly indicates the relative value of these forces at different crank angles and the extent to which they cancel each other. The resultant force shown is, of course, obtained by combining the two curves and represents the net out-of-balance force which, acting on the engine as a unit, produces vibrations having a periodicity of

twice the engine revolutions in a unit of time. When this situation was realized, attempts were made to minimize the out-of-balance condition. Reciprocating parts were lightened, connecting-rods were lengthened, it being understood that decreased angularity of the connecting-rod, as shown in Fig. 4, tends to bring about better balance conditions.

Lanchester, in England, must be credited with some very ingenious work which had for its object mechanism which would generate forces at the right time to offset the unbalanced forces described previously, and, had it not been for the demand for more flexible and smoother engines, there is little doubt that the four-cylinder out-of-balance condition would have been overcome in a practical way.

The next step forward was the six-cylinder engine and it immediately answered the demand for more power, more flexibility, more frequent power impulses and greater smoothness, which is primarily due to the inherent balance of the rotating and reciprocating parts.

The diagram of inertia forces in a six-cylinder engine, shown in Fig. 5, clearly indicates the relative value of these forces at different crank angles and how they cancel out, due to the location of the crankpins at 120 deg. with relation to each other. The resultant force is, of course, obtained by combining the three curves and graphically represents the perfect balance obtained by this arrangement. The six-cylinder engine is undoubtedly a type that will be represented for years to come owing to its inherent advantages; however, there are certain disadvantages which may be termed constructional that set definite limitations in its design. The crankshaft of a six-cylinder engine is necessarily long and space and weight limitations do not permit of the shaft being made as rigid as could be desired. In actual practice, therefore, there is a certain amount of periodic twisting of the crankshaft coincident with the several power impulses. At certain engine speeds a synchronous vibration is produced which results in a disagreeable sensation affecting the occupants of the car. This is, of course, more pronounced in the case of large six-cylinder engines in which the individual power impulses are particularly heavy. The speeds at which these vibrations occur are said to coincide with the "period" of the engine and the cause of these periods can be readily understood by a simple analogy. It is well known that a very slight push given at just the right time will keep a swing or pendulum oscillating, whereas the same force applied at certain other times will tend to modify or reduce the amount of swing. Accordingly, we find that if an engine has a period at 16 m.p.h. it may again have a period at 32 m.p.h., at 48 m.p.h., etc. The designer tries to build an engine which will have no objectionable period within the ordinary driving range. Lanchester again devised a possible solution of this problem with what is termed a vibration damper. This damper, shown in Fig. 6, consists of a small flywheel which is frictionally driven from the front end of the crankshaft, the main flywheel of course being fastened to the rear end of the crankshaft. This damper is effective in reducing the amplitude of the crankshaft vibration to such a point that it becomes negligible. It will be understood that the flywheel tends to rotate at a uniform speed and, when the crankshaft in response to synchronized impulses of the engine tends to vibrate or twist and untwist rapidly in succession, there is produced a certain amount of angular movement between the damper flywheel and its driving plates. The work of friction thus

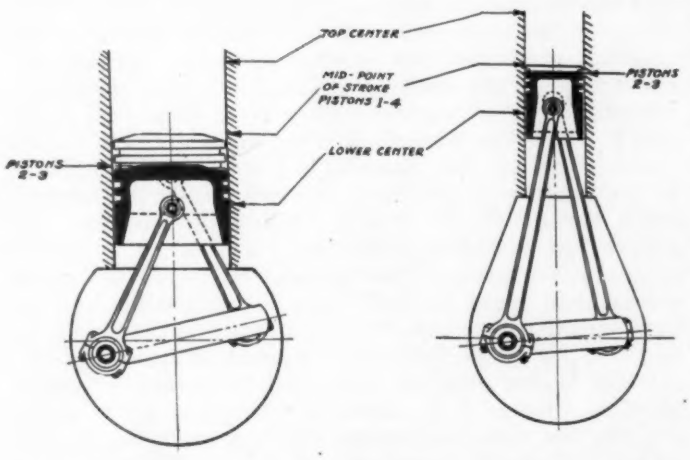


FIG. 4—CAUSE OF UNBALANCED FORCES IN A FOUR-CYLINDER ENGINE

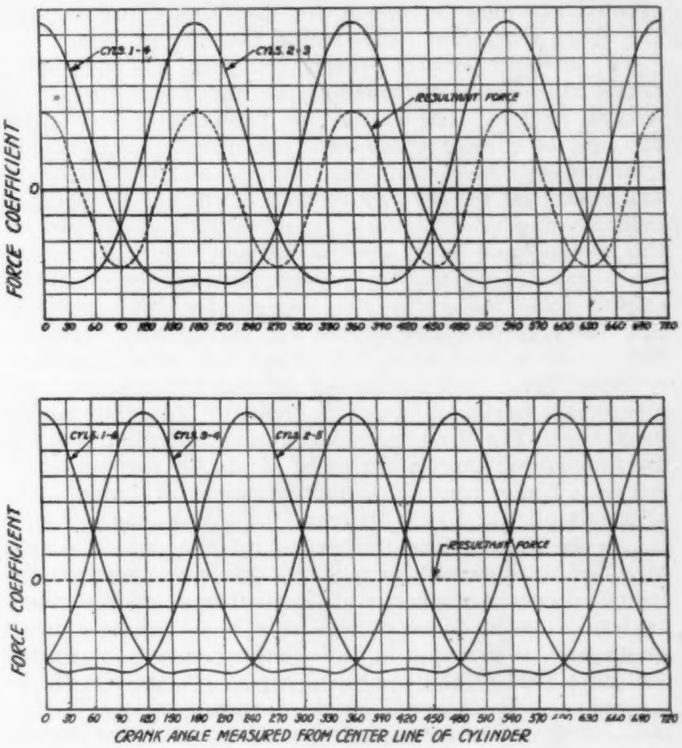


FIG. 5—DIAGRAM OF THE INERTIA FORCES IN A FOUR AND A SIX-CYLINDER ENGINE

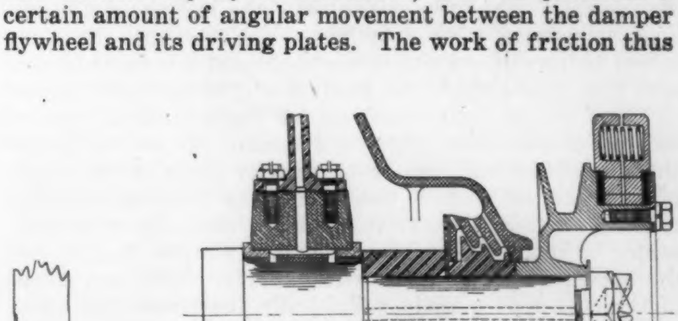


FIG. 6—THE LANCHESTER VIBRATION DAMPER

created provides the means for diminishing or dampening these vibrations by reducing their amplitude.

The demand for still greater flexibility and still better performance was responsible for the evolution of the V-type engine. The eight and twelve-cylinder engines can best be considered as two four-cylinder and two six-cylinder engines respectively, with a common crankshaft and crankcase for the two rows of cylinders. The eight-cylinder engine, therefore, inherits to some extent all the virtues and vices of the four-cylinder engine and the same can be said in regard to the twelve-cylinder engine with respect to the six-cylinder. We thus see that the eight-cylinder engine has as its chief drawback the out-of-balance condition associated with the four-cylinder, but in this case the unbalanced forces react and a resultant horizontal force is created. The diagram reproduced in Fig. 7 represents a simple method of showing the unbalanced inertia forces in a four or eight-cylinder engine. I have found this method very useful on account of its simplicity. This diagram is based on the principle shown in Fig. 4, and the extent of the out-of-balance condition is obtained by plotting the movement of the combined center of gravity of the pistons at various crank angles. It will be seen that this is a logical though rough way of arriving at the answer, because in reality the movement of the combined center of gravity of the pistons, due to lack of simple harmonic action, is the basic cause of the forces not cancelling out. The pistons in the right-hand cylinder block are shown at top and bottom dead-center and, assuming that the center of gravity of each piston is located at the center of the piston-pin, the location of the combined center of gravity of the four pistons in this block is arrived at by bisecting the distance as shown. The four pistons in the left-hand block are, of course, all in line, and making the same assumption their center of gravity will be found to be located at the center of the piston-pin as shown. Owing to the angularity of connecting-rods in this position, the pistons are located below the middle of their stroke as clearly shown by the arc struck from the center of the crankshaft. This arc, as shown in the diagram, passes through the mid-stroke position of each cylinder block and while it passes through the combined center of gravity of the four pistons in one block, when such pistons are located on top and bottom dead-center, it falls considerably above the center of gravity of the pistons in the other block. As before mentioned, the amount of this difference depends upon the rod-length-stroke ratio; the greater the ratio the less the difference and vice versa. By drawing a line through the combined centers of gravity in the right and left-hand blocks, and then bisecting it, the location of the combined center of gravity for the entire set of eight pistons can be located as shown at *c* in the diagram. It will be noted that this combined center of gravity falls to the right of the vertical center line and it is obvious that by rotating the crankshaft through 90 deg., the combined center of gravity will be moved to a similar location on the opposite side of the vertical center. This movement of the center of gravity graphically illustrates the magnitude and direction of the resultant force obtained by combining the inertia forces of two four-cylinder engines, with the cylinders located at an included angle of 90 deg. to each other.

In Fig. 8 I have shown a similar diagram illustrating the inertia forces in six and twelve-cylinder engines. In the right-hand block of this diagram two pistons are shown on top dead-center, and the other four pistons are of course lined up at a position somewhat above lower dead-center, due to the arrangement of the conventional six-cylinder crankshaft. Again considering the center of gravity of the pistons as located at the center of the piston-pin, it is only necessary to step off one-third of the distance from the center of gravity of the four pistons to the center of gravity of the two pistons, to arrive at the position of the combined center of gravity for the six pistons. By following out this same procedure in the left-hand block and then connecting the two centers of gravity thus found, we obtain a horizontal line which when bisected gives the location of the combined center of gravity, which falls exactly on the vertical center line as shown at *c*. If similar diagrams are plotted in any number of different positions of the crankshaft, it will be noted that the combined center of gravity of the two blocks does not move and it therefore follows that the combined center of gravity of all pistons in both blocks remains stationary. This diagram therefore is intended to show in a simple way that both six and twelve-cylinder engines are in perfect running balance. It is natural that for the same horsepower the individual cylinders of an eight-cylinder engine are considerably smaller than those of a corresponding four-cylinder engine and it therefore follows that because the reciprocating weights are lower there is a decreased tendency to cause vibration. The twelve-cylinder engine could be criticised on the score of a non-rigid six-cylinder crankshaft, were it not that the construction permits of a shorter and more substantial crankshaft, which is very much reduced in length over that of a six-cylinder engine of the same horsepower, and small cylinders with proportionately lighter power impulses. As far as automobile practice is concerned I believe that engines of not more than twelve cylinders will be practicable.

Number and Arrangement of Cylinders

Passenger cars are today built with four, six, eight and twelve-cylinder engines and, although there can be no clear line of demarkation between the various types, practical experience has resulted in certain definite conclusions as to the optimum cylinder bore for passenger-car engines in conjunction with a given maximum piston speed. Once this dimension is determined and a certain speed range for the engine is laid down, the question as to the number of cylinders becomes purely one of how much horsepower is desired. Generally speaking, for engines not exceeding 2000 r.p.m., a bore not to exceed 4 in. is satisfactory; where greater flexibility is desired a maximum speed of 3000 r.p.m. is permissible but the bore should not exceed $3\frac{1}{4}$ in. in this event. Hence we find that for small, light and inexpensive cars the four-cylinder engine provides a perfectly satisfactory power-plant so long as it is operated within the limits given above. The light medium-weight high-grade car is now almost universally supplied with a six-cylinder engine, which gives an improved result in the matter of smoothness as compared with a four-cylinder engine, with no decrease in economy as compared with a four-cylinder of the same displacement. When we come to consider a car of rather high horsepower for which a more flexible engine is desired, the choice lies between an eight or twelve-cylinder engine. The selection between these two would then depend upon the degree of flexibility and smoothness desired.

Truck engines at present have in practically all cases four cylinders, since the speed range of a truck has been confined within rather narrow limits by solid tires. The heaviest trucks have been geared as low as 10 m.p.h., and even light trucks on solid tires are limited to not

much above 20 m.p.h. over average roads; at these moderate speeds depreciation and maintenance charges due to road vibration are serious. Hence we find that a four-cylinder truck engine with a useful power range, from say 300 to 1200 r.p.m., has ample flexibility considering the moderate speed range over which it is economically advisable to run a truck on solid tires. However, we are now entering an era of pneumatic-tire development which bids fair to change radically the demands made on the truck engine. Pneumatic tires have been successfully applied to even the largest and heaviest trucks experimentally, and as a result high-speed truck operation instead of being very costly, due to rapid depreciation of the mechanism from the road vibration inseparable from the use of solid tires, becomes an economical proposition, greatly increasing the ton-mileage per day to be secured from a truck. This is of particular importance in the competition between railroads and trucks for "short-haul" work, over distances as great as 300 miles.

Let us now examine the relationship between pneumatic tires and the truck engine. I have already stated that the truck engine of the four-cylinder type is perfectly satisfactory for a speed range of 300 to 1200 r.p.m., which, let us say, corresponds to a speed range of 4 to 16 m.p.h. We can even run this engine up to 1800 r.p.m. and secure 24 m.p.h., but the wear-and-tear on the engine is greatly increased and its fuel efficiency decreased. The natural conclusion is that with the advent of pneumatic tires we must install more flexible engines in trucks and there is every reason to believe that truck engines will follow along similar lines of development to those of passenger-car engines, although the demand for an ultra-smooth truck engine is not likely to result in the use of more than six or eight cylinders at the most.

Originally the tractor powerplant consisted of a heavy-duty stationary gasoline engine, with very slight modifications to permit of its being portable. Insofar as cylinder arrangements were concerned the horizontal single-cylinder and the double-opposed two-cylinder types predominated. As the industry expanded the powerplant was brought uptodate and partook of the truck-engine type. We therefore find at present that tractors are almost universally equipped with four-cylinder vertical engines very similar to truck engines. In fact, the tractor engine must operate under conditions very similar to those of the truck engine but somewhat more severe, since the tractor engine is used as a stationary powerplant for running various kinds of farm machinery,

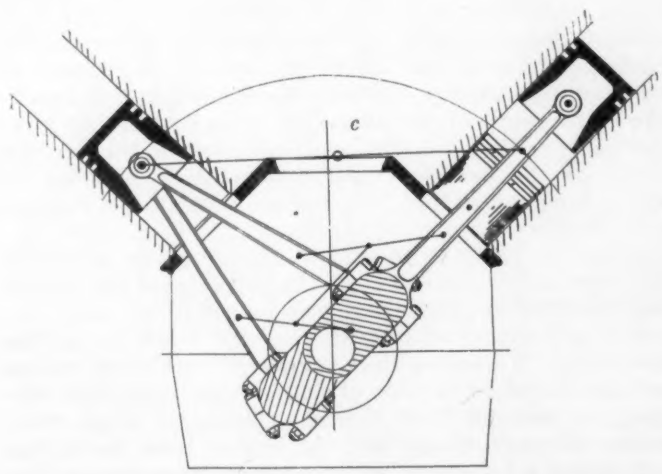


FIG. 7—UNBALANCED INERTIA FORCES IN A FOUR OR EIGHT-CYLINDER ENGINE

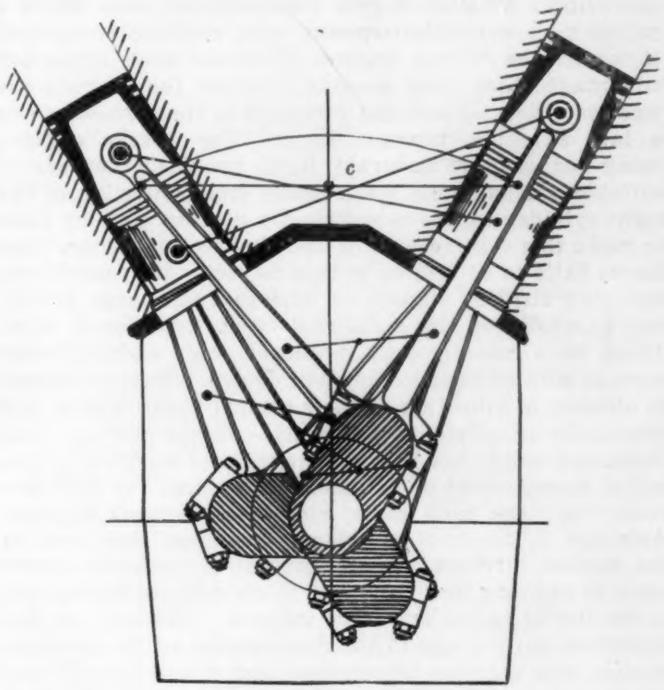


FIG. 8—UNBALANCED INERTIA FORCES IN A SIX OR TWELVE-CYLINDER ENGINE

in addition to its use for tractor purposes. Also, the tractor engine is generally adapted to use lower grades of fuel than the truck engine and, in addition, is supplied with air-cleaners to prevent dust from entering the engine through the carbureter.

When we consider aircraft engines in relation to the desirable number of cylinders, we are faced with altogether different problems. Although the aircraft engine owes its origin to the passenger-car engine, there is little in common between the two types. For instance, low weight is a prime consideration for aircraft work; in a car it is of secondary importance. Noisy operation is not a handicap with the aeronautic engine, since the propeller noise will always be a bar to silent operation of the powerplant, whereas quiet operation of the passenger-car engine is one of the points most sought. Good fuel economy under full load is a prime requisite for the aeronautic engine, in the passenger-car engine this is a matter of far less importance, good performance and flexibility with adequate gasoline mileage on partial loads being the factors striven for. There is one point in common between airplane and passenger-car engines which has a determining influence in the number of cylinders, and that is vibration. In the passenger car we seek for a sleek, smooth engine because that is what the passenger appreciates, in the airplane we must have a smooth engine, since neither the engine nor the structure of the plane can withstand the vibrations produced by a rough engine. The airplane engine is mounted on a few frail sticks or on some light metal stampings that form an adequate support so long as they are subjected to reasonable stresses, but the structure of an airplane cannot long endure the fatiguing stresses of a rough engine. The four-cylinder engine was therefore never popular for aircraft use. The six-cylinder engine we have seen is inherently in perfect running balance, but its length makes it rather heavy for a given power. Simplicity of manufacture, ease of installation, good accessibility and low head-resistance, contributed to making the

six-cylinder aviation engine successful in cases where a rather high weight-horsepower ratio could be overlooked. However, the V-type engines presented such important advantages that their general adoption for aircraft use was inevitable. First and foremost of these reasons was a low weight-horsepower ratio. The V-type engines being compact are naturally light, provided they are of suitable construction; the freedom from vibration of the eight-cylinder engine is sufficiently good in medium sizes to make this type acceptable and the twelve-cylinder type leaves little to be desired in this respect. We accordingly find that airplane engines of moderate and large powers are generally of the eight and twelve-cylinder V type. There have recently been developed some eight-cylinder engines with an included angle of 60 deg. which, in respect to absence of vibration at their normal flying speeds, are practically as satisfactory as twelve-cylinder engines. The discussion would not be complete without mentioning the radial arrangement of cylinders as instanced in both the rotary and the fixed radial classes of aircraft engines. Although this type of cylinder arrangement was used on the earliest airplane engines, present-day practice would seem to indicate that there are fairly definite limitations to the use of radial or rotary engines. However, at this extremely early stage in the development of the airplane engine, it is not wise to prophesy and it will be sufficient merely to consider a few of the outstanding limitations in respect to radial arrangement of cylinders. The head-resistance of such an engine is rather large, although, if the cross-section of the fuselage demands this area, it would not necessarily be a handicap to the use of such an engine. The matter of lubrication is none too easily carried out, since the position of the lower cylinders precludes the possibility of carrying any considerable amount of oil in the crankcase. An odd number of cylinders is invariably used to obtain a suitable firing sequence, which may be made a little clearer by reference to Fig. 9. It is obvious that such an engine built on the four-cycle principle must fire every alternate cylinder to secure evenly spaced power impulses. To secure more power radial engines have also been built in banks of two sets of cylinders, in other words, an eighteen-cylinder engine is produced by mounting one nine-cylinder behind another, both driving the same crankshaft. In general, the status of the radial and rotary engines is not very clearly defined and, although an immense amount of engineering work has been concentrated on their perfection, the V-type engines have made greater strides in the past few years. It is my belief that the field of the radial fixed-cylinder air-cooled engine is confined to moderate power units of not more than eleven cylinders.

The general requirements of a marine engine, insofar as its duty is concerned, are similar to those of the airplane engine, since both types must operate under nearly wide-open throttle for long periods and they must be equally reliable. Up to recent years marine-engine designers paid very little attention to weight and, in fact, some manufacturers boasted about the thick section utilized in their castings which, they claimed, gave the engine greater stability. This has proved to be more or less of a myth. It is far easier to produce a satisfactory result by using an engine which is inherently in approximately perfect running balance than it is to try to conceal an out-of-balance condition through the use of much excess weight, which of course does not respond to the vibration as would lighter parts.

In the matter of number of cylinders the marine engine field embraces every type listed above and, in addition, has produced engines with eight cylinders in line which were peculiarly adapted to the space limitations in a hull. However, it has lately become a practice in modern high-speed cruisers and speed boats to install airplane engines with slight modifications in the matter of cooling and drive arrangements. The great decrease in weight attained in this manner was immediately reflected in the improved performance of the boat, and the hull could also be made lighter. In slower boats the matter of weight is of far less importance, and here the influence of automobile design is somewhat more noticeable, in the use of block-cast cylinders, aluminum crankcases, enclosed valves, etc. However, I am confining my remarks at present to the number of cylinders, and about all that can be said is that the marine-engine field has a distinct use for each and every cylinder combination I previously referred to, from the one-cylinder engine, which is so popular as a rowboat accessory, to the huge twelve-cylinder engines found in palatial twin-screw or triple-screw cruisers.

Valve Arrangement

There are four different types of valve arrangement in common use, as illustrated in Fig. 10, classified as follows: (*a*) T-head, (*b*) L-head, (*c*) I-head and (*d*) a combination of (*b*) and (*c*), or superimposed, although sometimes the overhead valve is located directly over the other valve which occupies the normal L-head position. There has been much controversy as to the relative merits of the different valve arrangements. The argument will probably not be settled for years to come and it is possible that as long as the poppet-valve engine exists all of the different arrangements will be used. What we can consider, however, is the relative advantages and disadvantages of each type of construction.

Starting with the T-head type, this arrangement gives a symmetrical layout, a camshaft to actuate the inlet valves being placed parallel with the crankshaft on one side of the engine and a camshaft to actuate the exhaust valves being placed on the other side. This results in a very accessible engine, the carbureter and the inlet manifold being arranged on one side and the exhaust manifold on the other. The problem of driving the accessories is likewise rendered easy, since suitable drives can be provided by gears meshing with each camshaft gear. From a thermal standpoint the T-head engine represents the least efficient type. There is a large amount of water-jacketed surface in the combustion chamber which absorbs considerable heat from the explosion, so that the thermal efficiency is lowered. Unless double ignition is used, that is, one spark-plug over each valve, there is liable to be severe knocking under certain conditions, due to the action of flame propagation. It has been suggested by British authorities that this knocking is the result of the advancing wave of burning mixture compressing the unburned mixture in the farther recess of the cylinder until this mixture becomes so highly compressed that it detonates with all the violence associated with the term as distinct from an explosion. It is not necessary to go into this phase of the situation any more deeply than to state that experience has shown that knocking is particularly pronounced in a T-head engine where the spark-plug is generally located over the inlet valve. T-head engines permit of very large valves and are therefore capable of fairly high volumetric efficiency as distinct from thermal efficiency. High volumetric efficiency means that the engine takes in during each stroke a volume of mixture which approximates the theoretical volume represented by the displacement of the piston during its stroke. Large valves therefore mean

the minimum of restriction to the flow of the mixture into the cylinder and hence are conducive to high volumetric efficiency.

L-head engines, which at present are most commonly used, present the advantage of requiring the minimum number of operating parts. A single camshaft is used to operate both the inlet and exhaust valves and, as far as the camshaft is concerned, a single pair of gears or sprockets connecting it with the crankshaft suffices. The L-head engine is also superior to the T-head in the matter of combustion chamber exposed to the water-jacketed wall. This fact, I believe, is perfectly obvious and we have been able to obtain thermal efficiencies with small L-head engines which are fully as good as those obtained with any other valve locations in passenger-car engines. The volumetric efficiency possibilities of an L-head are slightly inferior to those of a T-head engine but, in practice, this difference is more than offset as a rule by the advantage gained in thermal efficiency. Incidentally the L-head engine, due to the minimum of moving parts, is capable of being made more silent in operation than any of the other types of poppet-valve engine, and silent operation is one of the most highly-prized qualifications in the automobile engine.

We will next consider the I-head arrangement. The overwhelming advantage to an I-head engine is that it presents a minimum amount of water-jacketed combustion-chamber wall and therefore comes nearer to forming the ideal combustion chamber, which would be hemispherical since the largest capacity for the least area of wall is contained in a sphere. We thus find that very high thermal efficiencies can be obtained with I-head engines and, owing to the ideal combustion chamber, very high compressions can be carried even in large-bore cylinders without preignition and detonation, provided proper material and thickness of wall are used. Hence I-head engines are universally used for aircraft work. The problem of operating the valves quietly has never been satisfactorily solved. The camshaft can be located adjacent to the crankshaft and the valves operated by suitable push-rods and rocker-arms as shown in Fig. 10, or it can be placed next to the valves, acting either

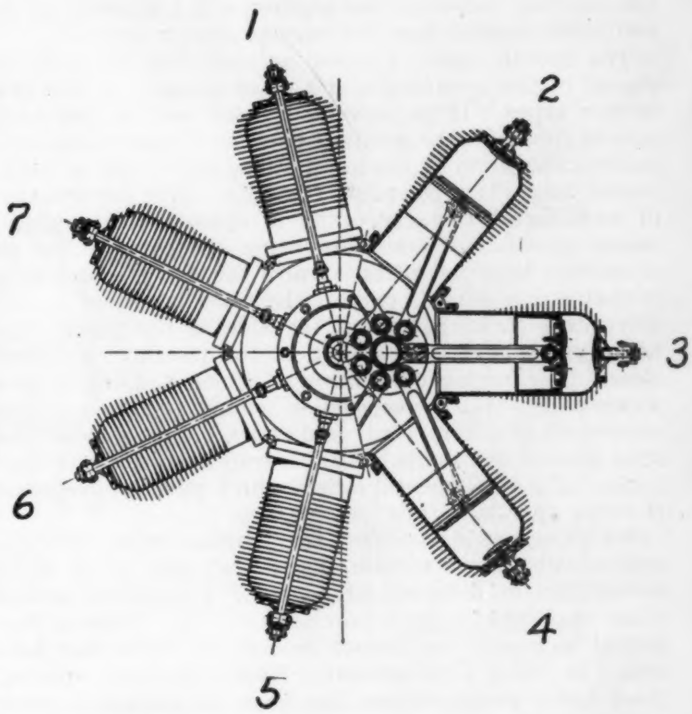


FIG. 9—ARRANGEMENT AND ORDER OF FIRING OF CYLINDERS IN A ROTARY ENGINE

directly on them or through suitable levers or rocker-arms. In this latter design two sets of bevel or spiral gears are necessary to drive the camshaft from the crankshaft and, in general, the increased number of moving parts necessary to operate overhead valves results in their operation being anything but quiet, especially after a certain amount of service when back-lash and play have developed in the various moving parts. Designers are struggling to overcome this handicap, but I firmly believe that this is only because they have been imbued with the idea that high volumetric and thermal efficiencies can only be obtained with overhead valves. This I believe not to be

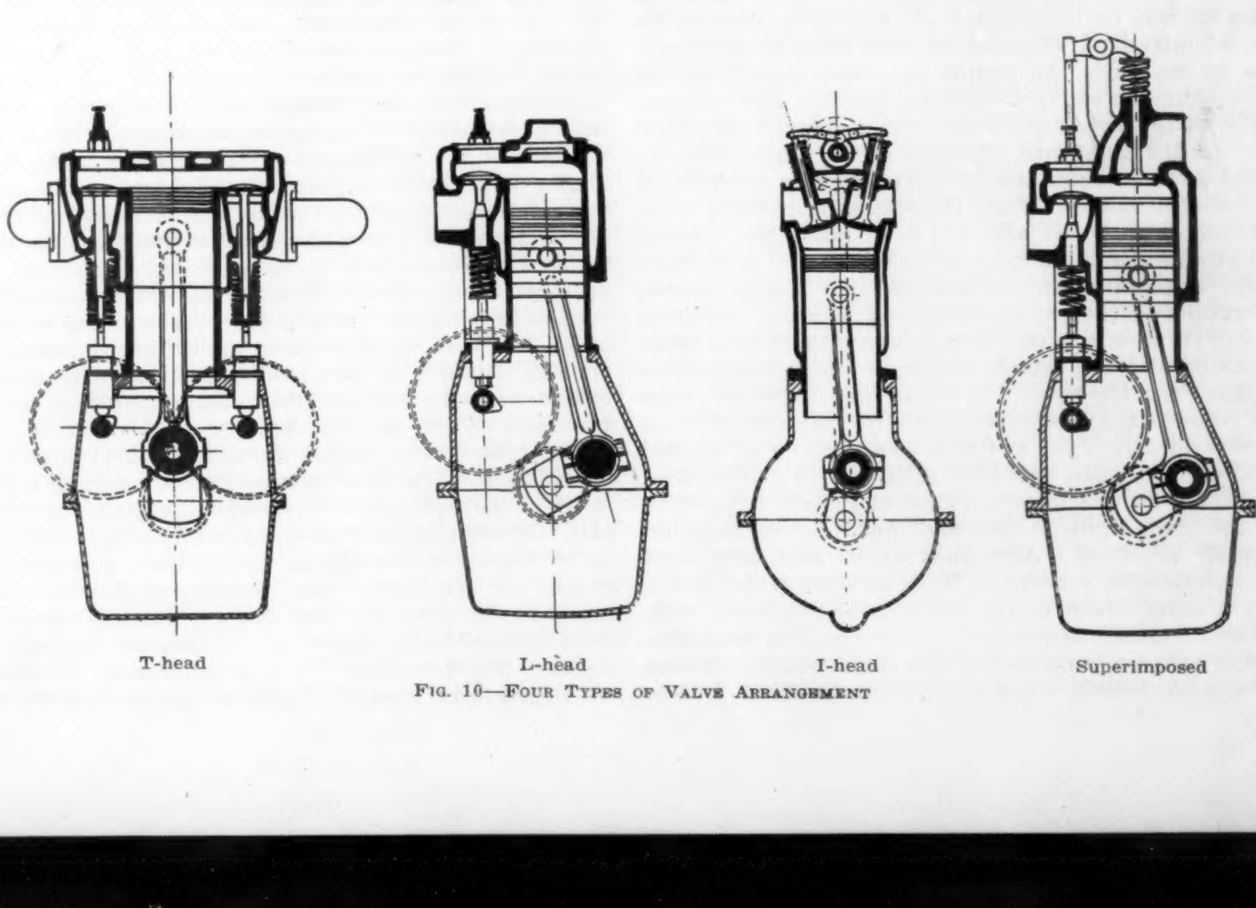


FIG. 10—FOUR TYPES OF VALVE ARRANGEMENT

the case with passenger-car engines, which are necessarily restricted to small bore for reasons already outlined.

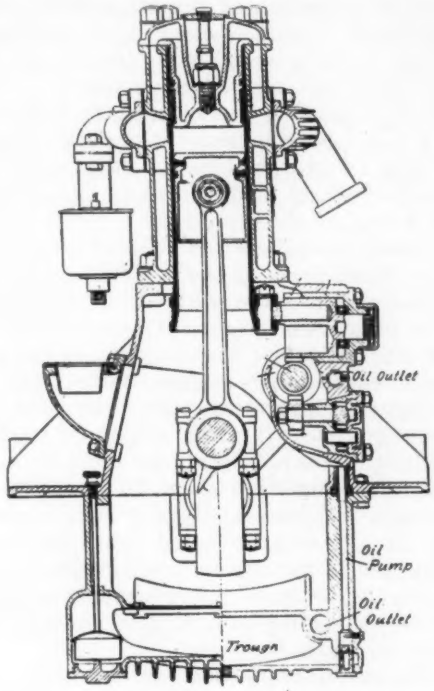
The fourth type of valve arrangement referred to shares in the advantages and disadvantages of the two former types. It is universally used with a camshaft located in the lower position parallel to the crankshaft, and the operation of the lower valve, which can be made rather large, is accomplished quietly. The introduction of push-rods and rocker-arms to operate the overhead valves introduces a noise-producing element. A fact in connection with operating a valve through a rocker-arm is that a considerable part of the noise is caused by the valve-stem striking against the side of the guide, this being particularly pronounced at the instant the valves close. The curved path through which the end of the rocker-arm works is responsible for a side thrust on the valve-stem which in turn produces a slight blow as the stem strikes the guide. I am merely instancing this as typical of a fundamental defect which must be overcome if silent operation is to be obtained.

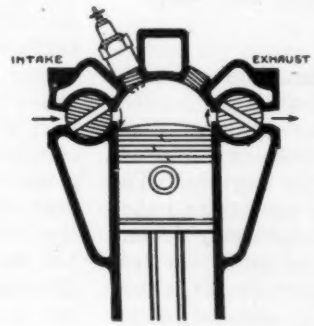
We have now considered the various valve arrangements, but there is little that I can say as to their suitability for different branches of automotive design other than what I have previously stated. From a historical viewpoint we cannot record any particular tendency in valve arrangement. Each and every one of these valve arrangements has been experimented with by practically all designers, and there is today apparently about as much difference of opinion on the subject as there ever was, with the single exception that aircraft engines are now invariably supplied with overhead valves, although L-head aircraft engines have been built in the past.

As regards valve material, there has been a steady improvement in poppet valves for all classes of internal-combustion engines. The earliest engines used automatic inlet valves which were opened by the suction of the engine and closed by the compression. The volumetric efficiency attained with such an engine was necessarily limited and mechanically-actuated valves are now invariably used except with certain types of stationary engines equipped with a hit-and-miss governor. This governor operates by holding the exhaust valve open when the engine exceeds its rated speed and with this combination the inlet valve naturally does not open when the governor is in action, since the engine can exert practically no suction with the exhaust valve held open. The material used in early valve construction was ordinary low-carbon steel. As the all-around efficiency of the engine was increased, a considerable amount of trouble was experienced with exhaust valves. When the engine is running with wide-open throttle for any length of time, the exhaust valve attains a dull-red heat and the ordinary steel valve rapidly oxidizes when exposed to such temperatures. This results in the valve not seating properly which in turn will result in a burnt valve in a very short time, since the leaking of the intensely hot gases during combustion will then raise the valve to a white heat. The first step taken to overcome this difficulty was to make the head of the valve of cast iron, and this was screwed or riveted to a steel stem. The cast-iron valve proved fairly satisfactory, but it was always found extremely difficult to keep the stem tight in the head and the heads would frequently break off. Alloy-steel valves were then used with considerable success, a high percentage of nickel giving a valve which would resist oxidation fairly well. With still further increase of mean effective pressures a higher exhaust temperature was developed and it was necessary to develop other alloy steels to stand the increased temperatures. It was found that 13 to 15 per cent of tungsten permitted the valve to attain a higher temperature without giving trouble, and such valves were considered satisfactory until airplane engines were fairly well developed. In some designs of airplane engine it is not possible to bring the cooling water as near to the valve seat as desired, and in such engines high-chromium valves were found desirable. These valves normally contained 10 to 14 per cent of chromium. For inlet valves, nickel steel has proved to be mainly satisfactory, it being understood that the inlet valves never reach any particularly high temperature, since they are kept cool by the incoming mixture.

I have already stated that, with passenger-car engines, silent operation is one of the most sought-after features. The ordinary poppet-valve engine has one noise-making element caused by the clearance between the valve-stem and the valve lifter or push-rod. It is, of course, necessary that the valve rest on the valve seat when closed, and this necessitates a certain amount of clearance between the valve-stem and the actuating mechanism. It is also a fact that the valve-stems increase in length as the result of expansion, due to the temperature rise in operation, so that when the engine is cold there must be from 0.003 to 0.006-in. minimum clearance between the valve-stem and push-rod. When the push-rod rises to open the valve a characteristic "click" is produced and, in early engines, the greater percentage of noise came from the valve-actuating mechanism. Later, by careful design, this noise was greatly diminished. First the valves were enclosed in a separate compartment which communicated with the crankcase so that a certain amount of oil mist lubricated the parts. Then again, by a careful study of cam contours, a design was evolved which permitted of the clearance between valve-stem and push-rod being taken up gradually, the push-rod acceleration increasing only after contact had been established between the valve-stem and the push-rod. Other factors in decreasing tappet noise, as it is called, consist in providing ample bearing surface for the valve lifter, so as to minimize the effect of side thrust produced by the cam striking the roller. Attention to these various details has resulted in tappet noise being reduced to a minimum, in fact the driving of the accessories presents a far more difficult problem at present insofar as silent operation is concerned. However, before poppet-valve mechanisms had been brought to their present state of development, there was a tendency for designers to look elsewhere for a solution of the problem of quiet operation. The Knight engine undoubtedly represents the most satisfactory result of these endeavors. This engine is shown in Fig. 11. Between the piston and cylinder there are two sleeves which are reciprocated by an eccentric shaft running at one-half engine speed. The setting of the eccentrics is such as to bring the ports in each sleeve in line with each other, and with other ports in the cylinder walls at such time as it is desired to establish connection between the combustion chamber and the inlet manifold, or exhaust manifold, as the case may be.

The rotary-valve engine shown in Fig. 11 requires no explanation. The third engine shown is a British design in which a single sleeve is caused to oscillate and reciprocate. In addition to some other disadvantages the sleeve-valve engine is necessarily longer than a poppet-valve engine of the same size. Rotary-valve engines have never really emerged from the experimental stage, the chief trouble being to secure a fit between the valve and its seat which will not leak when cold or seize under wide-open-throttle work. Summing up, it is questionable





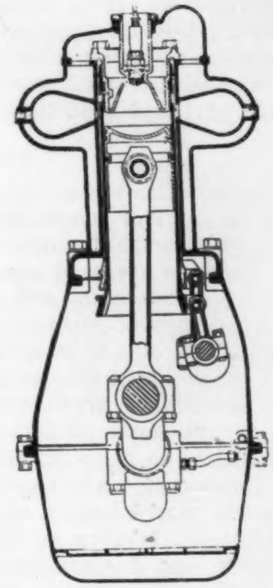


FIG. 11—SINGLE-SLEEVE, ROTATING AND DOUBLE-SLEEVE VALVE TYPES OF ENGINE

whether the slight gain in silence to be attained through the use of sleeve-valve engines warrants the added complications, weight and expense.

PISTONS AND RINGS

Pistons have received a considerable amount of detail development work, but the general design has not undergone any great amount of change. The most desirable characteristics in the piston are lightness, a low coefficient of expansion, good wearing qualities and good heat conductivity in the larger sizes. Lightness is attained by reducing the sections, if of cast iron, to a minimum. In small sizes the minimum thickness is as low as 5/64 in., and represents a fine example of the foundry art. Aluminum-alloy pistons are used successfully and have the advantage in the matter of weight over cast-iron pistons, even though it is necessary to employ somewhat heavier sections. The fact that aluminum is a better conductor of heat than cast iron works to advantage in large-size cylinders, especially for aircraft work where, if cast-iron pistons were used, the center of the piston head would attain excessively high temperatures which would cause preignition. The fact that aluminum expands more than twice as much for a given increase of temperature as compared with cast iron necessitates the use of increased clearance between the piston and the cylinder when using aluminum pistons. The result is that, when the engine is cold, a considerable amount of piston slap is encountered with aluminum pistons, and there are also greater chances for compression leaks and oil seepage past the piston with this greater clearance. These factors contribute to make the aluminum piston not altogether satisfactory for passenger-car use, but extremely satisfactory for aircraft and marine engines. Owing to the good bearing qualities of aluminum it is customary to allow the aluminum to come into direct contact with the piston-pin, which is made a somewhat tight fit in the piston when cold, and the expansion of the piston permits the pin to creep when hot. The piston-pin is generally allowed also to work in the upper end of the connecting-rod, which is fitted with a bronze bushing. Other types of piston have been made in the past, but have not achieved any particular success. These include two-piece pistons, comprising a steel head and a cast-iron skirt, and one-piece pistons which are cut away to present bearing surface only on those areas where the thrust is distributed, or where it is necessary to support the rings. Pistons are generally supplied with three piston-rings located in individual grooves which are machined above the piston bosses. Sometimes an additional ring, called a scraper ring, is located near the bottom of the skirt, so that its lower edge slightly overtravels the cylinder bore. This lower ring is sometimes effective in preventing an excess of oil from reaching the combustion chamber and is therefore often used with aluminum pistons to overcome the over-oiling tendency with the greater clearance.

The most satisfactory piston-rings are of the concentric type, in which the wall thickness is uniform all around the ring. The varying degree of elasticity which is required in the ring in order that it should tend to expand in a circle and fill the cylinder bore is attained by certain peening methods. The butting ends of the ring are generally finished to form a lapped joint at 45 deg. There has been much misrepresentation in the matter of specially designed piston-rings which attempt to form a more perfect seal than is afforded by the lapped joint. The fact is that the percentage of leakage past the joint is such a small part of the whole that any improvement in this regard yields results too small to measure. On the other hand, the simple ruggedness of the plain ring, as contrasted with the complicated construction associated with the majority of special piston-ring designs, has everything to recommend it for ordinary service.

There is no clear line of demarkation between piston design as practised by the different branches of the automotive industry. In general, pistons used in engines for light or medium duty, such as in passenger cars and trucks, are generally made of cast iron with small clearances between the piston and cylinder. On the other

hand, designers of aircraft and marine engines favor the aluminum piston largely on account of its better heat conductivity and lighter weight, resulting in decreased bearing loads. It can therefore be stated that aluminum pistons are particularly suitable for engines which develop nearly their maximum horsepower during the greater percentage of the time, while cast-iron pistons are used where part-load conditions prevail most of the time.

Crankshaft

Crankshafts in general use are made from one-piece drop forgings or sometimes machined from a solid billet. Built-up crankshafts are used in racing engines where ball bearings are used instead of plain bearings, and are also found in radial and rotary aircraft engines. The general design of the crankshaft depends upon the number of main bearings to be used, and this in turn may depend upon the whim of the designer or on some particular feature of cylinder arrangement which necessitates a certain arrangement of main bearings. In general, a designer tries to make an engine as short as possible, and the number of main bearings may have a considerable influence on the length of the engine. From a rigidity standpoint a bearing on each side of each crankthrow is desirable, and this has become practically universal practice in aircraft engines. This construction also simplifies the drilling of the crankshaft for oil distribution to the crankpins, since one cheek in each throw need only be drilled to form a communication between the hollow crankpin and an adjacent main-bearing journal.

Fig. 12 shows the various arrangements of main bearings found in modern four-throw and six-throw crankshafts. Where the crankshaft length is the determining factor three bearings are commonly used for both four-throw and six-throw crankshafts, whether they be for four or eight-cylinder or for six or twelve-cylinder engines respectively. A three-bearing crankshaft of this type is made very massive to minimize the deflection of the shaft between the bearings. The only serious disadvantage of making a crankshaft in this manner is that the crankpins and main-bearing journals, due to their large diameter, bring about a higher rubbing speed in contact with the bearing so that, for a given load, the bearing life is somewhat lowered. However, if the bearings are properly proportioned and adequate lubrication is provided, this influence can be neglected. The main bearing subjected to the greatest amount of wear due to heavy loads is the center bearing. To obtain a satisfactory firing sequence it is necessary that the two middle crankthrows of a four-throw or six-throw shaft should be in the same plane, and centrifugal forces acting on these two crankpins produce heavy loads on the bearing between them. In a seven-bearing or three-bearing shaft it is therefore customary to make the center bearing with considerably more bearing surface than the other bearings, except that the main bearing next to the flywheel must also be large to take care of the overhung flywheel.

The desirability of counterbalancing crankshafts is open to question. It will be recognized that, as a whole, both four-throw and six-throw crankshafts are inherently in running balance, or rather, such crankshafts would be in running balance, if there was no deflection or whipping of the shaft. To prevent what are commonly known as bearing knocks, which are particularly pronounced at slow speed and under full load, it is customary to use either a three-bearing crankshaft and make it sufficiently rugged so that the shaft will not deflect appreciably under heavy loads or a small shaft which is supported by additional main bearings. In either case the main bearings prevent any actual deflection of the crankshaft adjacent to the main bearings. Counterbalancing is accomplished either by bolting suitable weights to the cheeks of the crankshaft or sometimes the added material is forged integrally with or welded to the crankshaft forging. In general, from a practical standpoint, the chief advantage to be gained from counterbalancing a crankshaft is the reduction of main-bearing loading due to the lower centrifugal forces acting on the crankshaft. However, counterbalancing often introduces an objectionable result owing to the increased mass of the rotating parts, which cause the so-called period of the engine to be intensified as well as to occur at a lower speed. In exceptional cases counterbalancing is desirable; for instance, in the case of a very high-speed engine with comparatively small cylinders and very light reciprocating parts. In such a case the effect of synchronous vibration might be negligible, but the centrifugal forces acting on the individually out-of-balance crankpins might produce undue friction on the main bearings. A crankshaft for such service is shown in Fig. 13. It will be noted that the counterweights are attached to the cheeks opposite the crankpin in such a manner as to leave the minimum amount of clearance for the connecting-rod, to meet balancing requirements more perfectly.

Present tendencies in crankshaft design point to the use of three-bearing crankshafts of heavy design for four-throw or six-throw passenger-car engines, and five or seven-bearing crankshafts respectively for truck, tractor, aircraft and marine work.

Connecting-Rods

Connecting-rod design has been subjected to a gradual refinement process, and designers are fairly well agreed on what constitutes a good connecting-rod. The conventional connecting-rod is of I-beam cross-section and is a steel drop-forging. Tubular connecting-rods have been experimented with and used to a slight extent. It will be understood that a connecting-rod is alternately subject to compression and tension stresses together with a certain bending moment due to the oscillating character of the path of the lower end of the rod. The tubular section is adapted to resist bending stresses equally well from all sides, whereas the I-beam section is particularly efficient only in one plane. As the general rule in engine design the piston is exactly in line with the crankpin, so that bending strains are limited to the plane of oscillation and the I-beam section lends itself to resisting these stresses.

Lightness is almost as desirable a feature in the connecting-rod as it is in piston design, since the upper end of the connecting-rod represents reciprocating mass and the lower end an unbalanced rotating mass which, as a result of centrifugal force, throws a load on the crankpin bearing radially, out from the center. To gain reduction in weight it is the practice in high-class engines to machine the connecting-rod all over, since in this way it is possible to produce a light connecting-rod with a uniform cross-section, which could not be done with a drop-forged unfinished rod owing to variations in forgings. The lower end of the connecting-rod carries a bronze-backed babbitt bearing as a rule, although sometimes a die-cast bearing of suitable alloy is used. In a few cases the babbitt is applied directly to the steel connecting-rod, the rod being first suitably treated and tinned to form proper cohesion between the babbitt and the steel.

With the advent of the V-type engines there came about new developments in connecting-rod design. V-type engines follow either of two forms of construction. In some the right and left cylinder blocks are offset with

relation to one another and in others they are in line. There are as a rule several factors that enable a designer to determine which construction is the best for a particular purpose, and this phase of a design brings out clearly the fact that engine design cannot be based upon any particular feature but must be made a harmonious whole. In other words, the designer in starting to lay out a V-type engine cannot know what type of connecting-rod

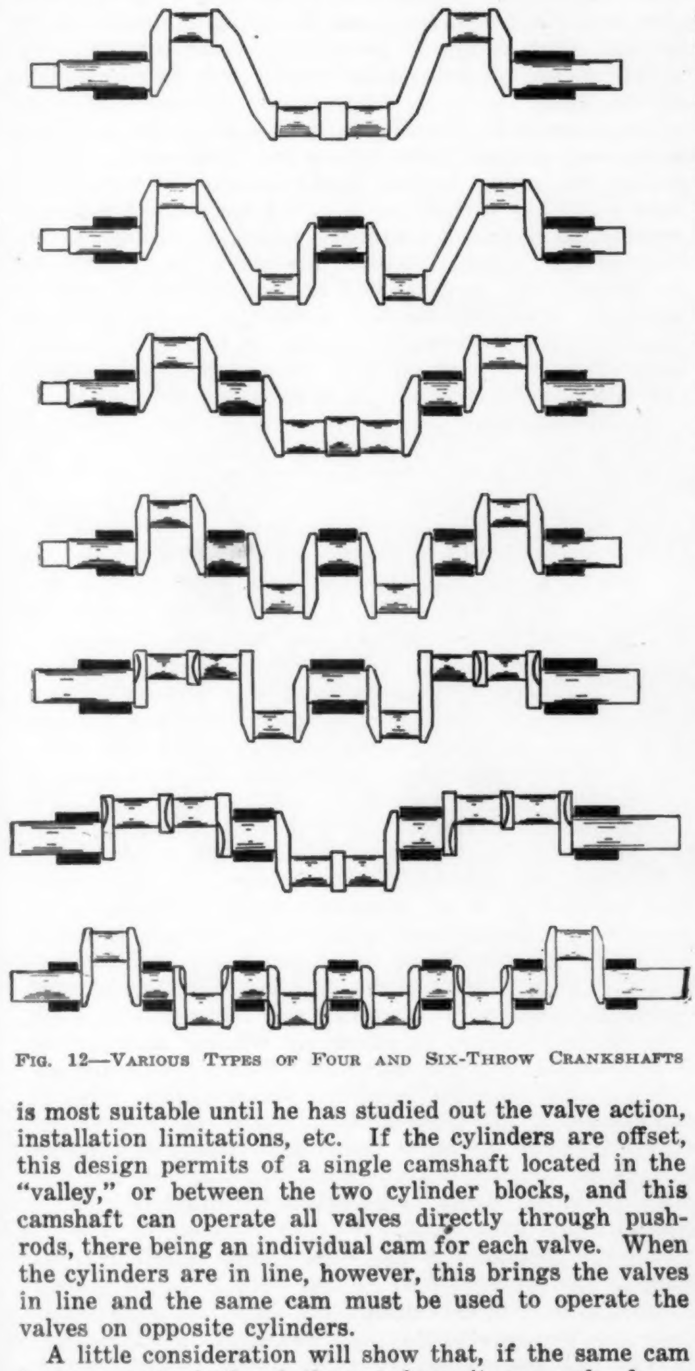


Fig. 12—Various Types of Four and Six-Throw Crankshafts

is most suitable until he has studied out the valve action, installation limitations, etc. If the cylinders are offset, this design permits of a single camshaft located in the "valley," or between the two cylinder blocks, and this camshaft can operate all valves directly through push-rods, there being an individual cam for each valve. When the cylinders are in line, however, this brings the valves in line and the same cam must be used to operate the valves on opposite cylinders.

A little consideration will show that, if the same cam is to operate both of these valves, it can only do so through the intervention of suitable rocker-arms which make contact with the cam at points either 45 or 225 deg. apart for a 90 deg. V-type engine, dependent upon the firing order adopted. Hence there can be no set rule as to whether to use a side-by-side connecting-rod as shown in Fig. 14, which is suitable for a V-type engine with the right and left cylinder blocks offset, or a pair of connecting-rods of the so-called straddle type, commonly used when the opposite cylinders are in line. In aircraft

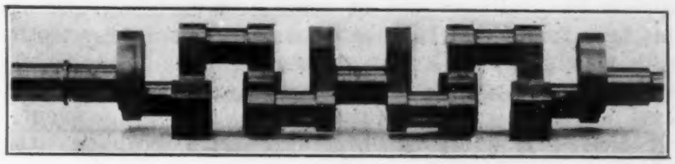


Fig. 13—A Counterbalanced Crankshaft

engines the latter construction is almost invariably used, since the overhead valves require individual camshafts in any event, and for the high bearing pressures employed a more satisfactory bearing is obtained in this manner. There are other types of connecting-rod which can be substituted for the straddle type, such as the articulated design which is particularly applicable to the "broad arrow" type of airplane engine which uses three or more blocks of cylinders instead of the pair of blocks associated with a V-type engine.

In general, connecting-rod design has been fairly well standardized and we find the drop-forged unfinished connecting-rod used in the cheaper grade of passenger cars and also for truck, tractor and marine engines. For high-class passenger-car engines and for aircraft engines, the connecting-rods are invariably machined all over. Considerable development work is still being done on connecting-rods with the object of reducing weight and cost, and some remarkable work has lately been done in connection with aluminum-alloy connecting-rods which are drop forged in a manner similar to steel forgings.

Flywheel

Flywheels on the early type of slow-speed engines were rather large in diameter and quite heavy. Cast iron was used as the material and the rim velocity was sufficiently low to make this construction satisfactory. The flywheel was fastened to the crankshaft either by a long taper fit or by a flange formed integral on the crankshaft. The latter construction is to be preferred and is practically standard now, since it is easier to remove a flywheel after having been in service and also it is not liable to work loose with use. When high-speed engines came into vogue the flywheel was considerably lightened, and with the advent of the unit powerplant the flywheel diameter was restricted by the size of the bell housing. The next step was to use steel flywheels to withstand the greatly increased centrifugal forces brought about by the high-speed possibilities of eight and twelve-cylinder engines as well as some six-cylinder engines. I have personally run such engines up to 4000 r.p.m., and for this work it is essential that the flywheel be of a good grade of steel and well balanced. Present-day practice is to make fly-

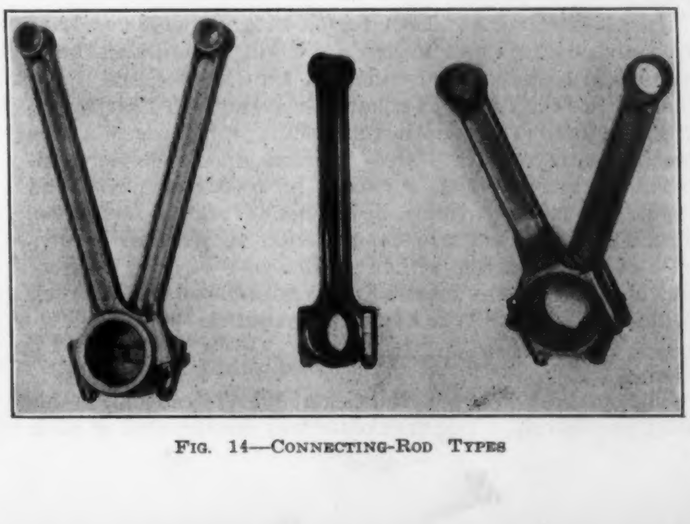


Fig. 14—Connecting-Rod Types

wheels for ordinary use of semi-steel castings, and it has been found that this material permits the gear teeth with which the starter pinion meshes to be cut integral with the flywheel. In a few cases a soft or hardened-steel ring gear is bolted to the flywheel and, in this event, for slow-speed work, ordinary cast-iron flywheels are satisfactory. Airplane engines are not equipped with flywheels as a rule, since the propeller serves as a flywheel if it is fastened direct to the crankshaft. However, in installations where the propeller is geared to the engine, small flywheels have sometimes been used, mounted on the crankshaft.

Crankcase

Crankcase construction has developed to a point where it can be said that each branch of the automotive industry has some special requirements which impose certain restrictions on the design of the crankcase. In early automobile engines the crankcase was made in two halves, and the crankshaft main bearings were contained half in the upper crankcase and half in the lower portion. This construction was very rigid but made it impossible to adjust or replace these bearings without dismantling the whole engine. It then became the practice to mount the upper halves of the main bearings in the main part of the crankcase to which the cylinders were bolted, and the lower halves of the bearings were supported in bearing caps. The lower half of the crankcase then became an oil-pan and could be made fairly light. For purposes of inspection the oil-pan could be removed without taking the engine out of the car. This represented a distinct advance from a standpoint of maintenance and is standard practice today. Early automobile engines were supported by a sub-frame, which generally carried the transmission case as an entirely separate unit. Considerable difficulty was experienced in securing the proper alignment between the engine and the transmission case, and the unit powerplant was then evolved. In this construction the crankcase is swelled out to enclose the flywheel in what is termed a bell housing. The transmission case is bolted directly to this bell housing, the butting faces being suitably machined to include a pilot, so that perfect alignment is insured. This construction eliminated the sub-frame, and the crankcase supporting arms accordingly reached out to bear on the side members of the main frame. Aircraft engine crankcases are invariably built according to the original automobile practice; that is, the crankcase is divided in a plane through the center of the crankshaft and the main bearings are carried between the two halves of the crankcase. This construction is favored since it is the lightest and most rigid construction, although in the matter of accessibility there is still much to be desired.

In marine engines both forms of crankcase construction already referred to are used but, in addition, large hand-hole covers are provided on the sides of the upper half of the crankcase to allow connecting-rod bearing inspection and even piston removal in some cases. This matter of accessibility in a marine engine is very important, since the engine cannot be readily removed and repairs must sometimes be made far from any base. Truck-engine crankcase construction in general follows automobile practice, although the use of unit powerplants is not by any means firmly established in the truck field. This is also true of tractor engines.

Lubrication System

The earliest engines relied on splash lubrication almost exclusively. The crankcase was constructed in such a manner as to accommodate a reasonably large supply of oil, and the connecting-rod caps were provided with suitable scoops which were immersed in the oil every revolution, thereby oiling the connecting-rod bearings directly and the main bearings, pistons, camshaft, etc., by the splash, which resulted in an oil mist permeating the whole inside of the engine. The next development was to keep this oil at constant level by adding a graduated amount of oil contained in an outside tank, which was supplied to the crankcase by plunger pumps having an adjustable stroke to permit proper calibration. Another method of lubrication which was fairly popular for European cars was a system of individual pumps, or a single pump distributing through a series of individual sight-feed glasses located where the driver could see and adjust the proper rate of flow. A series of pipes were then led to the various parts of the engine which it was desired to lubricate directly, and the oil ultimately reached the crankcase where it would serve to lubricate by splash such parts as had not been directly supplied with oil. While this method of lubrication was very efficient it was very complicated and extremely difficult to keep all the oil connections tight, especially in view of the vibration common to the engines at that time.

It was not until six-cylinder engines were developed which were capable of high speed that any important improvements in lubrication were effected. It was found that splash lubrication was not satisfactory for high-speed engine operation. To preserve a film of oil between a bearing and journal under pressures of as high as 1000 lb. per sq. in. the oil had to be supplied to this bearing under pressure. Thus it came about that the full-force-feed oiling system was evolved. The oil is generally circulated by a gear-driven pump which is submerged in the oil so as to require no priming. Other types of pump have been used in the past and are still used, but the gear pump has proved to be the most satisfactory for the purpose. A spring-loaded relief valve is generally used in conjunction with the gear pump and the spring is adjusted to maintain a maximum oil pressure which may be anywhere from 5 to 100 lb. per sq. in., depending upon the system of lubrication. Such a system is shown in Fig. 15 and makes a very neat self-contained layout with a minimum of pipe joints, the various shafts which are intended to be lubricated being made hollow so as to form ducts for the oil, which is thus carried throughout the engine, screened and recirculated. Such a lubricating system is extremely efficient and can be made economical in the use of oil. Full-force-feed lubrication is now standard in all high-class engines used in all branches of the automotive industry. In aircraft and marine engines the oil is sometimes circulated through an outside tank for the purpose of cooling and in some cases an extra pump is required to circulate the oil through the outside tank.

In some instances it has been found satisfactory to combine the pressure-feed system with a splash system of lubrication. In this design the oil is fed under relatively low pressure to the main bearings. It then finds its way into the crankcase, where it fills troughs which are placed in the proper relation to the connecting-rods so that they dip a predetermined amount at each revolution. The oil then overflows these troughs and finds its way back to the sump, from which it is again circulated. There have been many other systems of lubrication devised, but I have merely attempted to cover those which are in common use and have shown considerable merit.

So far as passenger-car engine lubrication is concerned full-force-feed systems commonly prevail, except in the

case of low-priced cars where the expense of drilling the crankshaft cannot be afforded and a high engine speed is rarely used. Truck, tractor, marine and aircraft engines of the latest types are invariably equipped with full-force-feed lubricating systems. There is one point in connection with this type of lubricating system which is not often realized and that is the tendency to over-oil the cylinders, particularly after the engine has been in service some time and the crankshaft bearings have worn slightly. The cylinders are generally lubricated by the oil thrown off the ends of the connecting-rod bearings especially and the main bearings to a certain extent. As these bearings wear they discharge more oil and consequently an excess of oil is thrown against the cylinder bore and on the piston, with the result that a steadily increasing percentage of oil finds its way into the combustion chamber, where it is consumed and causes the deposition of carbon. There are two methods of overcoming this difficulty, which exists in all full-force-feed systems; one, to intercept the oil thrown off from the bearings by suitable deflectors or baffles, the other, to equip the pistons with oil-scraper rings at the bottom of the skirt. Either of these methods can be applied to an engine so that the rate of oil consumption remains practically constant over long periods of service, but no one design is applicable to all cases.

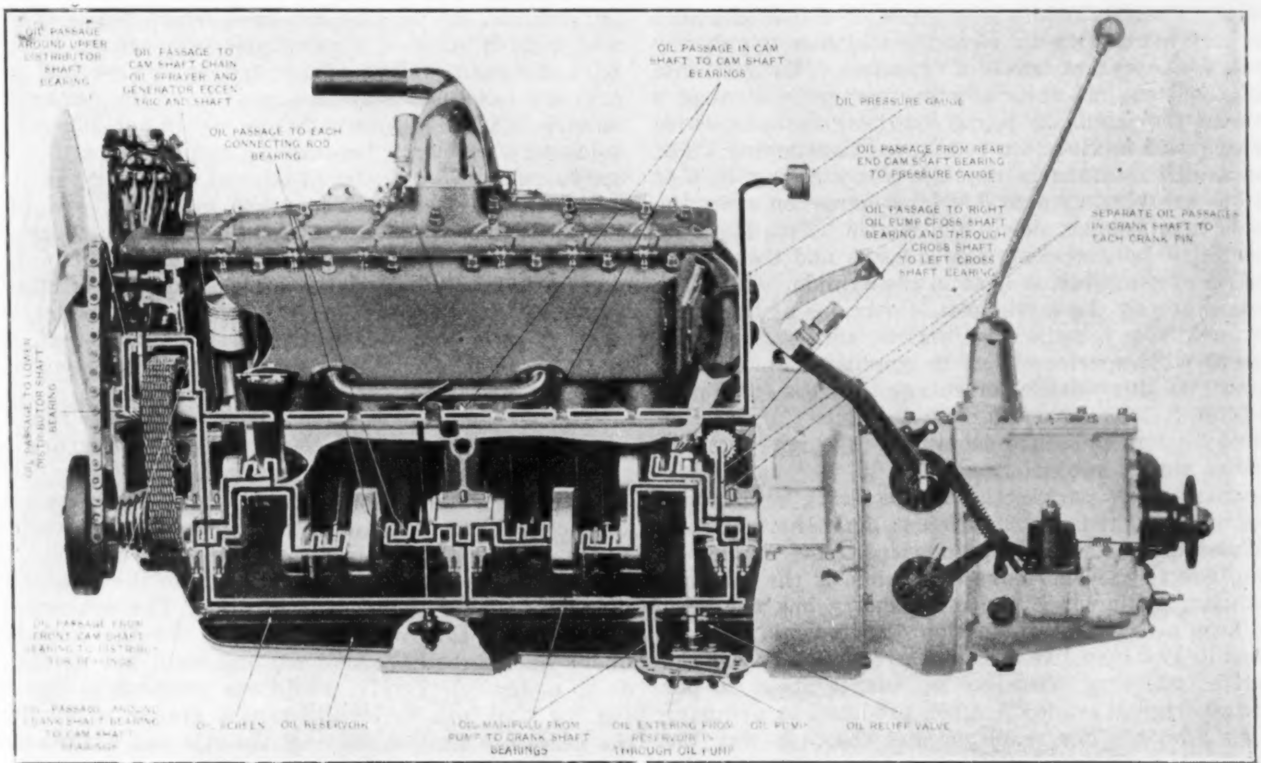


FIG. 15—THE FULL FORCE-FEED LUBRICATING SYSTEM

CARBURETION SYSTEM

The earliest forms of carbureters were very crude and were generally of the "surface" type. In these carbureters the air was either bubbled through gasoline or air was drawn over a surface wetted by gasoline through the medium of wicking or similar absorbent material. The first successful carbureters were really not very different from the instruments used today, at any rate in principle. All present-day carbureters work on the principle of drawing gasoline out of a jet, or series of jets, by a depression or slight vacuum created over the jet. The velocity of the air drawn in on the suction stroke serves to create this depression, and the jet is generally located in the throat of a venturi-shaped orifice which results in obtaining a high velocity without a corresponding restriction in the amount of air flow, since, as is well known, such an orifice has the property of building up a high velocity with little loss due to friction. The one basic trouble with this system of supplying a definite percentage of gasoline to the air is that for increasing rates of flow of air the percentage of gasoline or liquid fuel becomes greater and greater. It thus follows that all carbureters must use some compensating arrangement which in one way or other overcomes this tendency. I will not enumerate all that has been done along this line, but will describe merely the principal methods employed. In this connection, there has been little advance in carbureter design during the last decade insofar as the attainment of a perfect carbureter is concerned.

The first method used to overcome this increase in richness with a higher suction was to introduce auxiliary air above the jet in quantities to offset this tendency, and thus produce a uniform air-gas ratio for all engine speeds and throttle positions. This auxiliary air supply was controlled by a large light poppet valve held against its seat by a spring, and sometimes with a sealed diaphragm which would compensate to a certain extent for barometric changes. In other types of carbureters an auxiliary air valve, generally of a rotary type, was linked to the throttle and the ports of this auxiliary air valve were shaped so as to get an approximate result. This system, of course, is very satisfactory only so long as there is a definite relationship between the speed of the engine and the throttle position. Since in practice, however, due to the varying conditions of load, no such

fixed relationship exists, these carbureters can be considered as simple but crude compromises.

In another class of carbureters the gasoline is delivered from a constant level to a compound jet which forms virtually two jets, one of which is subject to a depression created in the venturi while the other is fed with a predetermined amount of gasoline which is represented by the gravity flow from the constant level to an auxiliary gasoline chamber or well. This combination results in a more or less uniform mixture for varying suctions and is very successful, since it combines a fair degree of accuracy with a very simple construction. The general principle is illustrated in Fig. 16. Other carbureters have been made using practically the same principle, but combining the two jets into a single one and arranging by suitable air bleeds that the flow of gasoline will be more and more weakened by an admixture of air as the suction increases. Practically all carbureters use a float chamber similar to that shown in Fig. 16, which automatically maintains a constant level of gasoline. To facilitate starting cold engines it is now customary to arrange a throttle in the main air supply to these carbureters so that a very rich mixture can be secured for starting. The reason a rich mixture is required for starting is that conditions are very unfavorable for combustion when the engine is turning over slowly and is cold. This is partly on account of natural compression leaks and then again to the loss of compression heat to the cylinder walls; the result is that only the more volatile portions of the gasoline are available for starting, that is, such fractions of the fuel as will vaporize under the conditions obtained at this time. As this volatile percentage is only a small part of the total, it is necessary to draw a quantity of gasoline into the cylinders to secure enough of the highly-volatile gasoline to start combustion with.

The question of carburetion is receiving an intense study at present, and the situation is little short of critical in view of the rapid depreciation in the quality of gasoline, due to the enormous expansion of the automotive industry with which the oil industry has not been able to keep pace. The production of petroleum has not increased in anything like the same proportion as has the demand for gasoline. Gasoline represents about 20 per cent of the original crude oil, when produced by ordinary refining methods. The result is that the only way the increase in demand for gasoline can be met is either by securing a higher percentage of gasoline from the crude oil, which can be done by various patented cracking processes, or by reducing the quality of the gasoline and using some of the heavier fractions which had hitherto been used for kerosene, etc. The results of using these heavier grades of gasoline in an engine which has not been designed to handle them are very serious. The temperatures generated in the cylinder under light load, which represents about 90 per cent of average automobile running conditions, are not sufficiently high to vaporize completely this heavier fuel. Accordingly some of the unburned portion, which we term for convenience kerosene, is deposited on the spark-plug. It subsequently forms soot, thus short-circuiting the spark-plug, and some of it finds its way past the piston and rings and dilutes the lubricating oil in the crankcase. In extreme cases a few hundred miles of running will serve to form a mixture of kerosene and lubricating oil which has extremely poor lubricating qualities. Continued running with this so-called lubricating medium results in burned-out bearings, scored cylinders and many other ailments associated with an engine which is improperly lubricated.

It is now universally recognized that the fuel must be supplied to the cylinders in a dry or completely vaporized condition, so that combustion will be complete and the troubles referred to will be eliminated. The simplest manner of obtaining complete vaporization is by supplying heat, and this in most instances is secured from the exhaust gas. The results of doing this are not altogether satisfactory, since, no matter what the method may be of conveying the heat from the exhaust gases to the intake mixture, there is bound to be an excess of heat supplied with a wide-open throttle or heavy-load conditions as compared with the light-load average running conditions. This excess of heat under full load seriously impairs the volumetric efficiency of the engine. If the temperature in the cylinder at the end of the suction stroke is the same as the atmosphere, and if atmospheric pressure conditions obtained in the cylinder at this time, we have 100 per cent volumetric efficiency. If, however, the mixture has been heated it has expanded and, even if we have atmospheric pressure we no longer have the same weight of air and gas as we had in the previous case, hence we no longer have 100 per cent volumetric efficiency. Actually, we never get 100 per cent volumetric efficiency because we cannot get atmospheric conditions in the cylinder at the end of the suction stroke, but by careful design of intake manifolds and proper proportioning of valve passages we are able to get very high volumetric efficiencies at medium speeds. If we now introduce a heated charge, the volumetric efficiency becomes less. This is only of consequence under wide-open throttle conditions, since it is obvious that, when the throttle is partly closed, we obtain very much less than atmospheric pressure due to the throttle.

Another fact which I wish to emphasize is that it is not nearly as necessary to vaporize the mixture completely before combustion, when operating with wide-open throttle, as it is on part throttle, for the reason that wide-open throttle implies maximum compression and hence the most favorable conditions for complete combustion which, of course, follows, due to the intense heat generated under wide-open throttle. The net result of all of this is that we must vaporize the fuel completely under part-throttle conditions, and need not necessarily do so under full-throttle conditions previous to introducing the fuel into the cylinders. A system of supplying the necessary heat under part throttle and automatically cutting it off under wide-open throttle conditions will now be described. This system accomplishes what is desired and is interesting in that it represents a device which must be applied to all engines in the near future to meet the present fuel troubles. I do not mean that this is the only way of accomplishing this result, but it represents the only way I know of at the present time.

The Fuelizer

Reference to Fig. 17 shows the fuelizer, as I have termed this device, applied to a twin-six engine. I will briefly describe how it functions. The principle of this device is to take advantage of the difference in pressure existing on either side of the carbureter butterfly-valve, and cause a small amount of the combustible mixture to pass through a passage which is parallel with the main carbureter passage, burn this mixture in a suitable burner and then allow the burnt gases to mix with the incoming main supply to the engine above the throttle. It is evident that this general scheme is at its maximum efficiency under low-throttle and light-load conditions; an intense heat is generated very promptly under these conditions, which are obtained when starting and when idling. On the other hand, under wide-open throttle con-

ditions, when we wish to maintain the volumetric efficiency of the engine as high as possible, but very little mixture passes through this "shunt" passage and a negligible amount of heat is produced in the burner.

The manifold as shown in Fig. 17 is of the conventional construction, except for the additional jacket used for the hot gas which communicates with the main intake passage through the two hollow "suction" plugs shown at *a*. The burnt gas joins the main mixture after coming through these holes, and the proportions are such that at no time does the burnt gas come into contact with the new mixture at a sufficiently high temperature to preignite the mixture.

The burner body is fastened to the manifold by the two-bolt flange shown, and in the burner body there is formed a combustion chamber into which a spark-plug fitted with a wide gap is inserted, as well as an observation window of heat-resisting glass which permits the action of the burner to be observed at all times. The mixture from the vaporizer is supplied by a 3/8-in. copper pipe and enters the combustion chamber after passing through a calibrated hole in the elbow shown at *b* on top of the burner and a screen *c*. The purpose of the latter is to assist in the atomization and even distribution of the incoming mixture. The mixture is supplied by the vaporizer shown at *d*, which is composed of four main parts, the choke *e*, the jet *f*, the jet sleeve *g* and the air intake *h*. The vaporizer is intended to function as a carbureter through a limited range of depressions.

In actual operation, when the engine is idling, combustion takes place in the burner silently and continuously and a bluish-green flame completely fills the combustion chamber. This flame diminishes in intensity as the throttle is opened and the depression in the main intake header is thereby decreased, the general result being that for ordinary driving conditions up to 25 m.p.h. a mixture temperature of 150 to 180 deg. fahr. is maintained, giving perfect distribution, excellent acceleration, absence of spark-plug fouling and elimination of dilution

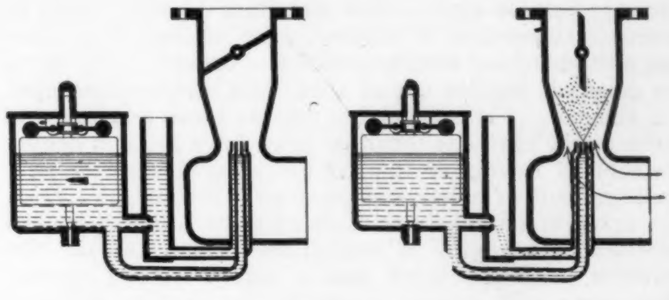


Fig. 16—The Conventional Type Carbureter

of the lubricant in the crankcase. At higher speeds and wider throttle opening the influence of the fuelizer gradually decreases until at wide-open throttle it is practically out of action, which is exactly the condition desired. This combination has permitted the running of a twelve-cylinder engine on kerosene at moderate driving speeds with practically the same results as when using gasoline, but when using kerosene there are critical temperatures below which we cannot go without considerable spark knock. The problem of burning kerosene is, of course, something that we do not yet face, but the design of this heater can be modified to permit any shape of temperature-load curve desired.

The airplane engine has even a greater need for a device like the fuelizer than has the engine used on the ground, but for somewhat different reasons. Engine failure in the air represents the only real danger confronting the pilot, and if this liability did not exist flyng would undoubtedly be safer than any other form of rapid transportation. Accordingly, every step we take to diminish the possibility of engine failure in the air brings us nearer to putting aviation on a safe, commercial basis. One of the chief causes of engine failure is the result of loading, as it is termed, or the failure of a cold engine to respond to the throttle, particularly after idling for

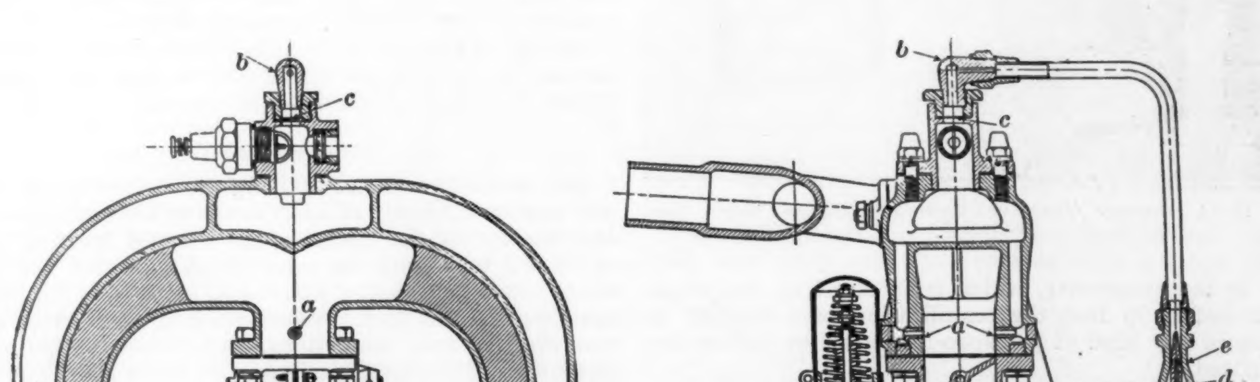


Fig. 17—The Fuelizer Which Has Been Developed to Assist in Securing Maximum Fuel Economy

an appreciable time. This condition is very liable to occur just previous to landing, after gliding down from an altitude of say 8000 to 10,000 ft. Cross-country flying is generally carried out at about this altitude and, even in summer, it is appreciably cold at these heights. As soon as the engine is throttled down for a glide, it begins to cool off rapidly so that, if the pilot should require a sudden spurt of power just previous to landing, to correct an error of judgment or to avoid some hitherto unseen obstacle, the engine is very liable to fail to take the throttle, with the result that a forced landing ensues, frequently with serious results to the machine and possibly the pilot and passenger.

A Liberty engine equipped with a pair of fuelizers is shown in Fig. 18 and, in some recent tests, remarkable results were achieved. In this particular engine the carbureters have been placed in a low position to the rear of the engine and are connected to the main intake manifolds by rather long pipes. The object of this construction is to obtain gravity feed from the gasoline

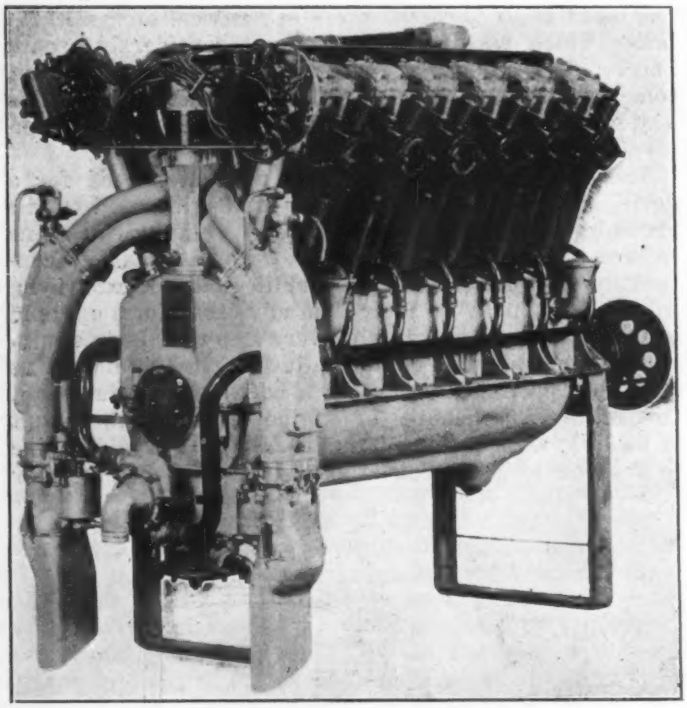


Fig. 18—A Liberty Aircraft Engine Equipped with Two Fuelizers

tank to the carbureter, which is in itself an important aid to safety in that the complications and liability to failure of any kind of pressure-feed gasoline system are eliminated.

Normally, such an intake system, due to its greater length, is even more subject to loading after idling than the conventional short manifold, and yet, when equipped with the fuelizer, with the engine chilled nearly down to the freezing point, it is possible to run it at idling speeds as long as desired and at any time obtain instantaneous response to a sudden opening of the throttle, the acceleration under these severe conditions being as good if not better than that of a thoroughly heated engine. It will therefore be recognized that the fuelizer definitely eliminates the possibility of engine failure under the condition already outlined. Furthermore, there is every reason to believe that spark-plug fouling, another contributing cause of airplane-engine failure, will likewise be eliminated through the use of the fuelizer, as it has definitely accomplished this in the case of the automobile engine.

The application of the fuelizer to marine engines likewise constitutes an important improvement. Here the conditions differ somewhat from both the airplane and automobile requirements. Marine engines, in common with airplane engines, are built to obtain high volumetric efficiencies at their normal operating speeds and this necessitates the use of large manifolds and intake passages. At low engine speeds the velocity of the mixture through these large passages is necessarily low, with the result that the liquid fuel is deposited on the walls and tends to drain back to the carbureter. The nature of the propeller load on an airplane engine is such that it is not called on to develop any considerable power at low speeds, whereas the marine engine is oftentimes required to develop high torque at low speeds, particularly when getting under way or reversing. Since the intake mixture velocities at low engine speeds are too low to carry along the liquid gasoline particles, it follows that there is a definite low-speed limitation on the operation of the ordinary marine engine which necessitates racing the engine while maneuvering, to prevent stalling which might result in a collision. When equipped with the fuelizer, however, the engine is supplied with a dry mixture at these low speeds and consequently the engine will throttle down and run regularly at extremely low speeds, and can be relied upon to develop full torque instantly if required to do so.

The reason so much space has been devoted to the subject of the fuelizer is that it concerns the most pressing need of the present-day internal-combustion engine. We are facing a critical period in the development of the internal-combustion engine because we must either limit the consumption of gasoline, which would entail strangling the growth of the industry, or we must modify the engine so that it will deal with fuels which are quite different from what we have been using in the past. In making this statement it is not intended to disparage the efforts of those who have achieved some wonderful results by the cracking processes but, no matter what refining methods are used, it is evident that the industry in the future must be better able to cope with heavier-grade fuels than it has been in the past.

Ignition System

The earliest means of igniting the charge in the cylinder was by allowing an open flame to communicate with the interior of the cylinder, the time of ignition being controlled by a suitable valve which admitted the flame to be communicated. The next step was "hot-tube" ignition. In this form a tube heated by an external torch was screwed into the cylinder and served to ignite the mixture. After the engine had run for a short time the tube would stay hot, so that the torch was no longer needed. The time of ignition was controlled in a crude manner by the size of the orifice leading from the combustion chamber to the hot tube. Much trouble was experienced with this form of ignition, the tubes burning out and blowing out very frequently. Electric ignition quickly followed, of both the so-called low-tension and high-tension systems.

The low-tension system was referred to as a "make-and-break" system, comprising a hammer and anvil inside the cylinder and mounted on a plate. It was so arranged that the hammer could be moved away from the anvil by a suitable mechanism on the outside of the cylinder. The anvil was insulated from the plate and connected

to a battery through an induction coil carrying a single heavy winding. Later, a low tension magneto was used as a source of current. It generally consisted of a stationary armature wound with a single heavy winding, and a shuttle which revolved between the armature and a permanent magnetic field. One of the ends of the armature winding was grounded and the other end connected to all anvils for a multiple-cylinder engine. The system is shown diagrammatically in Fig. 19, and the circuit was closed just previous to ignition by bringing the hammer in contact with the anvil either positively or by a spring. At the moment of ignition the hammer would be tripped by a suitable push-rod operated off the camshaft, and a very fat spark would be produced between the hammer and anvil. In general, make-and-break ignition was very efficient, providing that the different push-rods were kept adjusted and the magneto was kept synchronized with the make-and-break mechanism. However, the delicate nature of the mechanism demanded considerable attention and the make-and-break ignition system was finally abandoned about 1907, except for stationary engines where it is still sometimes used. An improvement in the mechanism consisted in actuating a hammer by an electric magnet which was energized by the same current that produced the spark, but the greater simplicity of the high-tension system finally made it practically universal.

The high-tension ignition system depends upon a current of several thousand volts jumping a gap approximately 1/32 in. wide inside the cylinder. This is provided by a spark-plug. The high-tension current was originally obtained from vibrating coils connected to a battery. The coils were provided with primary and secondary windings, the primary being connected to the source of the electric current by a suitable commutator and the secondary winding being connected to the spark-plug. A great many variations of this arrangement are possible, such as an individual coil for each cylinder, which necessitates only a low-tension commutator, or a single vibrating coil for all cylinders, which necessitates in addition a high-tension distributor, or a single vibrator, called a master vibrator, which breaks the primary current in the coils serving successive cylinders, through suitable connections to the commutator. The source of current may also be a low-tension alternating-current generator, such as is used in the Ford automobile. This type of high-tension ignition gave fair satisfaction, but many important elements vital to perfect ignition are lacking. One of these requirements is that all cylinders should receive their spark at the same relative position of piston travel. Another is that this point of ignition must be the same irrespective of engine speed, that is, assuming the advance and retard mechanism is fixed, in other words, there must be no "lag" of the spark at high speed. Another requirement is that the spark intensity must not sensibly diminish at any speeds within the operating range of the engine. All these requirements were first successfully met by what is termed the true high-tension magneto illustrated diagrammatically in Fig. 20. In this magneto the armature, which is of the Siemens type, revolves in a suitable permanent magnetic field and carries two windings, a primary and a secondary. The primary winding consists of a relatively few turns of heavy copper wire and the secondary consists of several thousand turns of fine wire. An interrupter is mounted on the end of the armature shaft and is arranged to open the primary circuit at the instant when the rate of change in the number of magnetic lines passing through

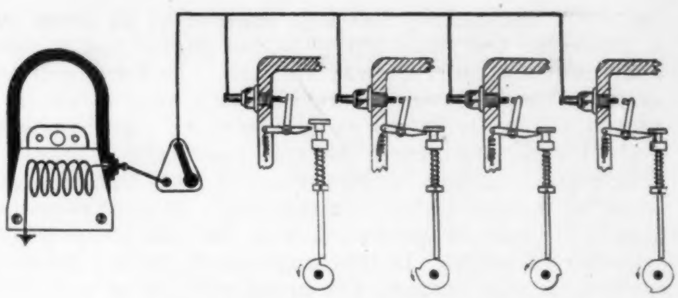


Fig. 19—The Make-and-Break Ignition System

the armature is at a maximum. A condenser is connected across the interrupter contacts and this results in a heavy induced current being generated in the primary winding which, in turn, produces a high-voltage current in the secondary winding. This high-voltage or high-tension current is led to the particular spark-plug through a suitable distributor, which delivers the current to the spark-plugs in the firing order desired.

In addition to the true high-tension magneto there were other types in which the armature carried only a primary winding, and the primary current, which was induced in the same manner, was discharged into the primary winding of another coil generally mounted on the dash. A secondary winding on this same coil supplied the high-tension current to the spark-plug. In other magnetos the armature was stationary and a suitable shuttle, or rotor, caused the magnetic lines to vary in the armature. For several years the true high-tension magneto was supreme in the ignition field. Extremely good workmanship was needed in their manufacture and when well made they would run for very long periods without attention. If the magnets were made of suitable material their life is very long. Platinum and platinum-iridium interrupter contacts were alone found suitable. To obtain a good spark when cranking the engine by hand, it was necessary to build the magneto with an extremely small air gap between the rotor or armature and the field poles. The secondary winding was extremely delicate and was subjected to the centrifugal forces produced by high-speed rotation, as well as the shocks incidental to sudden variations in speed. All of these circumstances tend to make the magneto expensive if built right, and very troublesome if not built right. Very few magneto manufacturers were qualified to turn out reliable instruments.

About 1912 electric starting and lighting was brought out, and every car was provided with a large storage

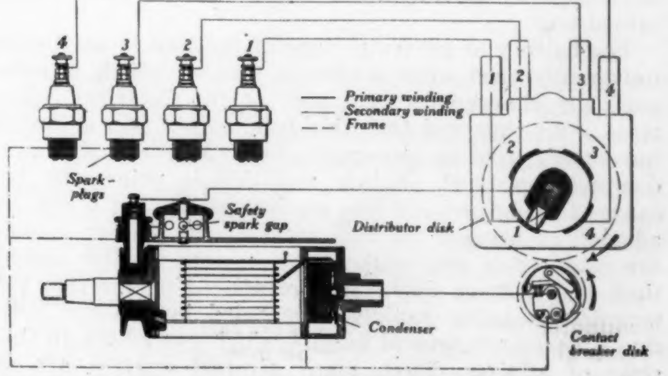


Fig. 20—Wiring Diagram of a High-Tension Magneto-Ignition System

battery. The battery was kept charged at all times by a generator that was driven by the engine and a constant source of current was available. Battery ignition systems were accordingly revived and very much improved. What is known as "single-spark" ignition was evolved and very shortly became practically universal. Single-spark battery ignition differed from the original forms of battery ignition in that these latter invariably used a vibrator in connection with the coil which gave a shower of sparks. In this single-spark battery system current is sent through the primary winding and the circuit is opened by an interrupter at the instant the spark is required. The collapse of magnetic lines in the core of the coil serves to induce a high-tension current in the secondary winding, which breaks down the spark gap and produces a single spark. A typical single-spark battery system is shown in Fig. 21 and comprises a battery, an ignition switch, an ignition coil, a resistance unit, an interrupter, a condenser and a high-tension distributor. There has been much controversy as to the relative merits of battery ignition and magneto ignition systems. The fact is that at present battery ignition is universally used when a battery and generator are part of the regular equipment of the engine. Battery ignition is not advisable unless the battery is kept charged automatically. Magnetos accordingly are used to a large extent on trucks and tractors where electric starting and lighting has not yet gained a foothold. From a performance standpoint there is little to choose between the two systems. The battery system furnishes a spark of greater intensity at the lower speeds, whereas the heat of the magneto spark increases with speed up to a certain point. This difference in the characteristics of the two systems has given rise to many arguments. The hot battery spark is conducive to excellent idling, starting and low-speed running, the increasing spark intensity with speed of the magneto dispenses with the need of an automatic-advance mechanism which is part of most battery-system installations. This mechanism consists of a centrifugal governor which changes the relationship of the interrupter cam with its driving shaft as the speed is increased. As far as reliability goes, the battery system is undoubtedly superior in one respect. There are no close clearances or difficult insulation problems in the battery system as compared with the magneto, so that with the average grade of workmanship it is far easier to produce a good battery system than it is a good magneto. The battery ignition coil can be located wherever desired to protect it from heat, moisture and vibration, which is not the case with the magneto. From an engine-design standpoint it is far simpler to provide a drive for a battery ignition system than it is for a magneto. The chief advantage of the magneto remains that it is a self-contained unit.

The battery or generator type of ignition is practically universally used when a storage battery which is automatically charged forms a part of the electrical equipment. We thus find that this form of ignition is almost universally used on passenger cars. Magnetos still predominate on truck engines and this is principally because starting and lighting equipment are not generally adopted at present for this service. In tractor service the magneto is also supreme to an even greater extent than in the truck field. In aircraft-engine ignition the magneto is being rapidly superseded by battery ignition. There are several factors which contribute to this state of affairs. First, many aircraft engines are of the V-type, with an included angle which does not give evenly spaced impulses. This has been done in some cases to reduce periodic vibration, and calls for ignition sparks which are not evenly spaced. While magnetos can be built to suit this condition, it is necessary to sacrifice certain features in the design. With a battery system any desired ignition-timing arrangement can be obtained by merely modifying the contour of the cam. Secondly, aircraft are generally supplied with batteries and generators for other purposes, such as wireless telephone or telegraph systems, lighting, heating, etc. If battery and generator equipment is available the additional ignition equipment, if of the battery type, can be added with little increase in weight as compared with magnetos. In actual service, battery ignition has proved very satisfactory for aircraft use.

Starting System

Electric starting and lighting equipment plays an important part in the operation of the modern internal-combustion engine, and it now appears as if this equipment can be considered an essential one for all branches of the automotive industry. It is true that electric starting is universally used only on passenger cars at present, but marine engine, aircraft engine and truck and tractor engine manufacturers are rapidly adding this to their equipment. The first electric starting and lighting equipment comprised what is termed a single-unit system. This was a compound-wound motor generator which, when used for cranking, was geared to the flywheel at a ratio of about 25 to 1 and which was operated from twelve storage-battery cells connected in series. When it was used as a generator, which was after the engine had started, the motor-generator was driven at a much reduced speed, about engine speed or somewhat more, and was arranged to charge the battery with the cells connected in parallel. A commutating switch was connected to the linkage used to change the gear ratio. This system was fairly efficient in operation, the chief drawback being that the cells were charged in parallel. This is known to be very poor storage-battery practice, since it is impossible to distribute the charging current equally among all the cells. Furthermore, if one cell should become short circuited, all the other cells discharged through it. The next step in the development of the motor-generator was to provide two separate windings on the same armature, each winding having its own commutator. This system operated from a three-cell or 6-volt battery and electrically functioned the same as the two-unit systems which were later developed. Two units can now be considered standard, although the single-unit is still made in large quantities. In the two-unit system illustrated diagrammatically in Fig. 22, the starting motor represents one unit and the generator the other. The starting motor is of the series type and is of very low resistance. They are extremely efficient and very light, considering the horsepower developed. A representative starting motor will weigh about 20 lb., develop about 1 hp. and have a maximum efficiency of 70 per cent. Automatic gear-meshing means are generally employed so that, when the starting switch is closed, the gear on the armature shaft automatically meshes with the flywheel gear and, when the engine has started, the armature gear is automatically thrown out of mesh. The generator is substantially of the same size as the starting motor but the windings are very different, the generator armature being wound with many turns of comparatively fine wire, whereas the starting-motor armature has a few turns of heavy wire. The generator field winding is composed of many turns of fine wire and is connected in shunt with the armature instead of in series, as is the

case with the heavy field winding used on the motor armature. The principal problem in connection with the generator is the means of regulating the output. The generator must function through a very wide speed range, say from 400 to 3000 r.p.m., and it must keep the storage battery fully charged but not overcharged. Many systems of regulation have been tried, both voltage and current regulation being used. If a generator is controlled to give constant voltage at all speeds it produces the ideal result. When the battery is low or discharged, the difference in voltage between the battery and generator is considerable and a heavy current flows from the generator to the battery. When the battery becomes fully charged its voltage approaches that of the generator and the current is automatically decreased. However, voltage regulators are quite delicate, require great care in their manufacture and are therefore somewhat expensive. Constant-current regulation has also been used but it is not as desirable, since if the current is high enough to take care of an occasional heavy current drain it will result in overcharging batteries in a great many cases.

A form of regulation which is very popular at present is third-brush regulation. This system takes advantage of the phenomenon of armature reaction; the field is excited by one of the main brushes and an auxiliary brush placed between two main brushes. The output of such a machine is represented by a steadily rising current up to a certain speed, generally corresponding to about 25 m.p.h., after which point the current gradually diminishes until at maximum speed it may have only one-half its peak value. While this system would appear to be very crude, it is a fact that the general results in service are fairly satisfactory. The reason is that heavy current requirements correspond invariably to slow driving and, at high speed, the demand for current is as a rule reduced. The output of these generators can be regulated by shifting the third brush around the commutator. In addition to the regulating means the generator must be supplied with an automatic cut-out relay, which is a device to connect the generator to the battery at such speeds at which the generator is capable of charging the battery and, of course, in slowing down to disconnect the battery from the generator to prevent any reversal of current, which would discharge the battery. Generators as a rule are driven at as high a speed as possible without introducing noise into the drive. Practically, it is not feasible to drive the generator much faster than one and one-half times the engine speed.

Starting and lighting equipment are now universally

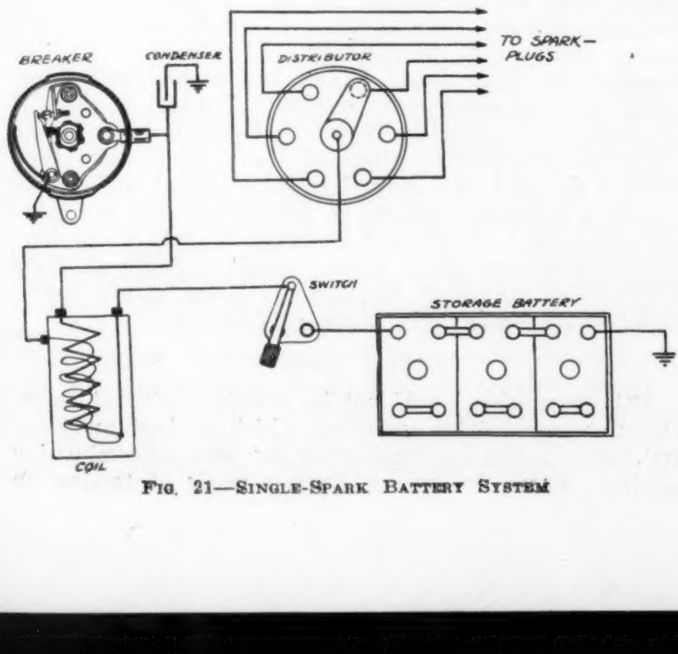


Fig. 21—Single-Spark Battery System

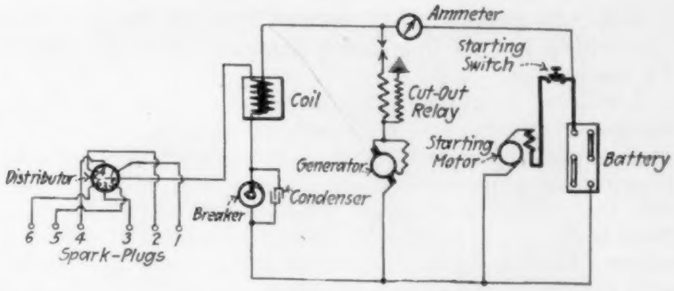


Fig. 22—Two-Unit Storage-Battery System

applied to passenger-car engines. Truck engines are in nearly all cases adapted to receive starting and lighting equipment, but this apparatus is not generally applied. However, there is an increasing demand for this equipment, although in the matter of reliability, starting and lighting equipment and particularly the battery have not shown themselves capable of withstanding the severe service incidental to the use of solid tires as satisfactorily as passenger-car equipment running on pneumatic tires. The increasing use of pneumatic tires in connection with trucks will doubtless be a factor in extending the use of starting and lighting equipment for trucks. Tractors are very seldom supplied with starting or lighting equipment, although tractors equipped with very large engines require some mechanical means of starting the engine. During the war, searchlights and generating equipment were frequently used on tractors at night. However, the average tractor, in common with other farm machinery, receives so little attention, especially during the winter, that it is doubtful whether starting and lighting equipment will ever become popular in this field, since the storage battery requires a certain amount of periodic attention.

Aircraft and marine engines are rapidly being supplied with starting and generating equipment. For both of these cases the starting equipment is almost indispensable, especially with the steady increase in the size of the engines.

I have confined this discussion of starting systems exclusively to electric equipment, although compressed-air starters were used to some extent previous to the introduction of electric starters, but they have been practically all discarded in favor of the latter system. The basic reason for this is that the storage battery represents the lightest known reservoir of energy available for direct conversion into mechanical power. In other words, a compressed-air tank will be very much bulkier and heavier than a storage battery for the same capacity in horsepower hours.

Cooling System

The problem of cooling the internal-combustion engine has received much attention and the requirements are now thoroughly understood. The temperatures inside the cylinder during combustion are about 2000 deg. fahr. and, unless the walls of the cylinder were kept cool by some external agency, the pistons would seize, since no lubricating oil could withstand such temperatures; furthermore, preignition would seriously interfere with the operation of the engine. We talk of air-cooled and water-cooled engines but, except in the case of marine engines, all engines can be said to be air cooled, some indirectly and others directly. The indirect method is by circulating the water around the cylinder jackets and then through a suitable radiator. Air is forced through the

radiator by reason of its passage through the air when the vehicle is traveling, aided generally by a fan driven by the engine.

I will give a simple practical example showing why a water-cooled engine is preferable to an air-cooled engine from a design standpoint. A representative medium-size six-cylinder automobile engine is provided with a radiator, the wetted surface of which totals something like 8000 sq. in.; that is, the air drawn through the radiator comes in contact with that much surface which is available for transfering the heat from the water to the air. If this engine was made without any water jackets, the external area of all the cylinders would total something like 400 sq. in. In other words, the air would have to take away 20 times more heat from a given area of metal. In air-cooled engines it is therefore necessary to increase the effective cooling area of the cylinder walls greatly. This is done as a rule by forming a large number of cooling fins or flanges integral with the cylinder. Furthermore, for passenger cars, when using air-cooled engines, it is necessary to cut down the mean effective pressure to diminish the amount of heat to be dissipated.

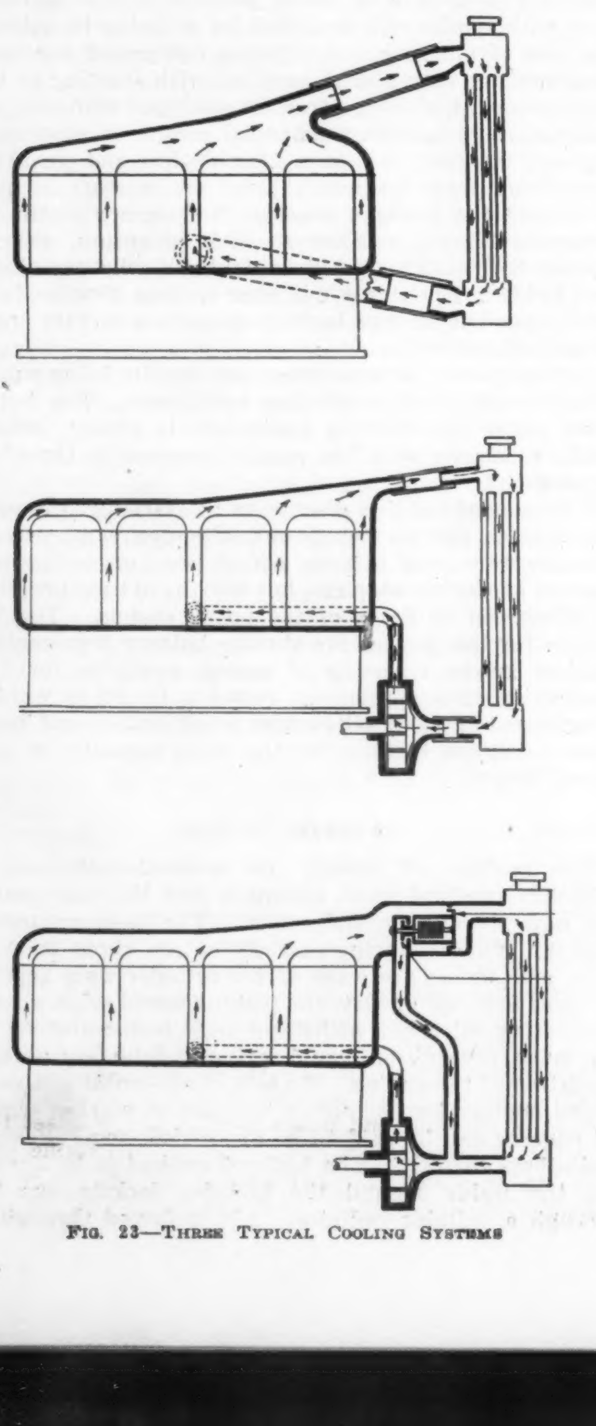


FIG. 23—THREE TYPICAL COOLING SYSTEMS

Aircraft engines, however, present important inducements for air cooling, especially in conjunction with a fixed radial or rotary type of engine. In such designs the cylinders are each exposed to substantially the same amount of air flow, and the air velocities in the propeller slipstream attain very high values. Furthermore, the load on the engine decreases with a decrease in speed, so that it is possible to operate aircraft air-cooled radial or rotary engines at nearly as high mean effective pressures as can be done with water-cooled engines. There is no doubt, therefore, that air cooling of aircraft engines of the radial or rotary types will continue to find favor with designers of such engines.

There are two different methods of circulating water around the cylinder jackets and through the radiator. These are pump circulation and thermo-syphon circulation respectively. In the pump-circulation system the water-pump is driven by the engine, generally at about one and a half times the engine speed. This pump is invariably of the centrifugal type at present, except in the case of marine engines where gear pumps are commonly employed owing to their superior priming characteristics. A centrifugal pump is to be preferred because it involves the use of a minimum number of wearing parts. In thermo-syphon circulation systems natural circulation is depended upon, the heated water rising to the top of the cylinders and thence through the water-outlet connection to the radiator, where, as it becomes cool, it gradually sinks to the bottom of the radiator and thus the circulation is continuously effected. In thermo-syphon systems it is necessary that the water passages be very large, since any restrictions would necessarily slow down the rate of circulation, which is already many times slower than a pump-circulation system. Generally speaking, a larger radiator must also be employed. A natural advantage of a thermo-syphon system is that, while the engine is cold when starting, the water does not start to circulate instantly, which permits the engine to heat up more rapidly than in the case of the pump-circulation system. However, by the use of an automatic valve operated by a thermostat in conjunction with a pump-circulation system, as shown in Fig. 23, it is possible to secure the advantages of a thermo-syphon system in the matter of bringing the water up to a desired temperature as quickly as possible.

Summing up, we find that passenger-car engines are almost exclusively water-cooled, the air-cooled engine being represented in very few cases. One reason for this condition is that air-cooled engines necessitate overhead-valve construction, which involves the use of more complicated valve-actuating mechanism with an attendant increase in noise, whereas the water-jacket of the water-cooled engine has the additional advantage of muffling some of the valve noise. Truck, tractor and marine engines are invariably water cooled. Aircraft engines of the vertical or V-type are now practically all water cooled, although air-cooled engines of these types have been used in the past to a limited extent. Radial engines are usually air cooled, especially in the smaller sizes, but there appears to be a pronounced tendency to apply water cooling to this type also. Rotary engines, however, have always been air cooled, but they are being rapidly superseded by the other types of aircraft engines.

ENGINE TESTING

This discussion would not be complete without reference to engine-testing equipment which has been an essential factor in the development of the internal-combustion engine. There are two distinct methods of testing an

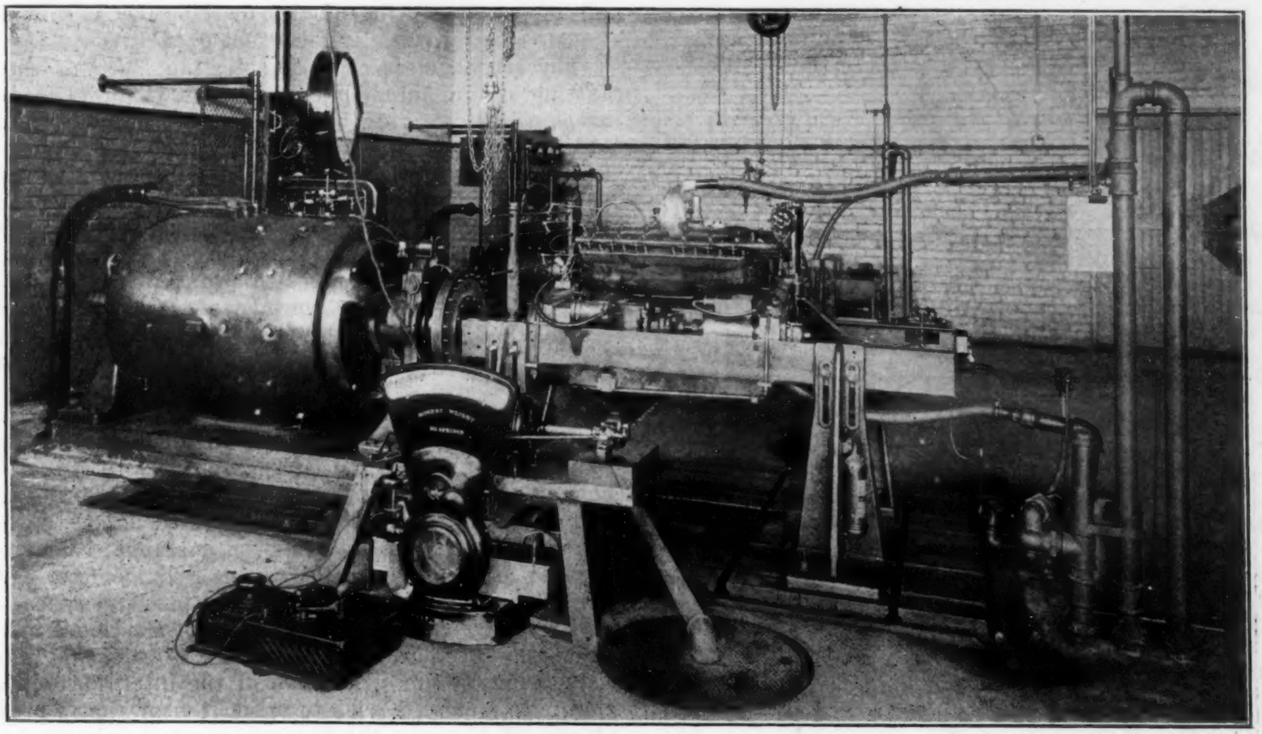


FIG. 24—A TYPICAL DYNAMOMETER INSTALLATION FOR ENGINE TESTING

engine; one, a dynamometer test and the other, a test after installation in the car, truck, tractor, plane or boat, as the case may be. Both kinds of test are necessary, each method permitting of acquiring certain data indispensable to a complete understanding of the subject. The dynamometer represents a means of absorbing power and may consist of a prony friction brake, a water brake, a fan brake or an electric-cradle dynamometer. I will describe only this latter form since it is immensely superior to the other types and is universally used, at least in this country.

A typical electric dynamometer installation is shown in Fig. 24. The dynamometer consists of a generator, adapted also to run as a motor. The field frame of this generator is mounted on ball bearings and is carefully balanced. The engine to be tested is connected by a suitable coupling to the armature shaft and the field is separately excited. The current generated is dissipated in suitable resistance grids and no electrical readings are taken. The load on the engine is varied by a suitable field rheostat and, in addition, the resistance grids can be connected in various groups to obtain the desired load. The actual load on the engine is represented by the torque on the field frame of the generator, and this is measured by suitable scales such as are shown in Fig. 24 on the far side of the dynamometer. When making a power test, therefore, the torque readings are given directly by the scales and the speed readings are obtained by suitable tachometers, or preferably by a positively-driven revolution counter.

A typical power curve is shown in Fig. 25. It will be noted that the torque is plotted against the ordinates shown on the right-hand side, which give the pounds pull at 21-in. radius, this being the distance from the center of the field frame to the point where the weighing scales are attached. The revolutions per minute are plotted against the abscissas and the brake horsepower is obtained by multiplying the number of revolutions per minute by the pounds torque and dividing by 3000. The brake mean effective pressure is given in pounds per square inch and is obtained by multiplying the number of pounds torque by a factor varying with the displacement of the engine. Gasoline consumption is plotted on a basis of pounds of gasoline per horsepower-hour. In actual testing the gasoline consumption is obtained by the difference in weight of the gasoline supply tank before and after a run, which may vary from 1 to 15 min., or longer, depending upon the degree of accuracy desired. The usual procedure is to obtain the required data over the entire speed range of the engine in a series of steps, the speed increase in successive runs being about 200 r.p.m.

The oil consumption of the average internal-combustion engine is somewhat difficult to measure over a comparatively brief interval of time. In Fig. 24 there is shown in the foreground one method which has proved very satisfactory. Except in aircraft and marine engines all internal-combustion engines of the types we are dealing with employ what is known as a wet sump. This means that the oil is continually being circulated through the engine and back into a sump formed integral with the lower half of the crankcase. In making an oil-consumption test with the apparatus shown, the oil-pump driven by the engine is removed and a suitable trough installed under the crankcase so that, as the oil is returned to the sump, it will fall into the trough and thence fall into the tank shown on the scales. In this tank there is suspended a suitable pipe coil through which hot or cold water can be circulated to maintain the oil at the desired temperature. This temperature must be held constant within narrow limits if accuracy is desired, since a slight change in the temperature of the oil materially changes its viscosity and hence the balance is upset between the oil which is in circulation in the engine and the oil in the tank. A small gear pump driven by an adjustable-speed electric motor draws the oil out of this

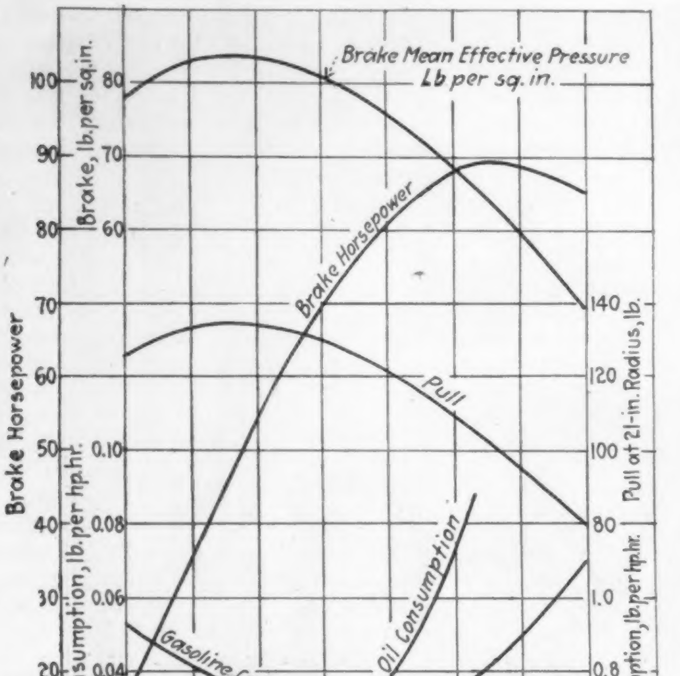


FIG. 25—A TYPICAL SET OF ENGINE TEST CURVES

tank and discharges it into the oil manifold provided in the engine. In actual practice it is possible to obtain very accurate and consistent results with this apparatus over a run as short as 3 hr. Some engines will use as little as 6 oz. of oil in this time, running at about 1200 r.p.m. wide open, while others may use ten times this amount. One very important precaution which must be taken when running an oil-consumption test is to prevent any portion of the fuel from diluting the oil. I have referred to this condition at some length previously, and it is only necessary to state that a dry mixture must be supplied to the engine if the true oil consumption is to be ascertained.

In addition to routine tests such as outlined, the electric dynamometer permits much other information to be obtained. For instance, the dynamometer can be used as an electric motor to turn over the engine and, by taking the readings of the torque required and the revolutions per minute, a friction-horsepower curve can be arrived at, giving the mechanical efficiency of the engine under these conditions. This information, however, is of comparative value only, since the actual mechanical losses are very much greater when the engine is running under its own power due to the gas pressures. Carbureter settings, ignition and valve-timing, and many other variables can be investigated to the best advantage on the dynamometer.

There has recently been brought out an optical indicator which promises to be of invaluable assistance when used in connection with dynamometer testing, since the variations in power output of the individual cylinders can be arrived at, thus leading to important clues as to the all-important matter of the distribution of a uniform mixture to all cylinders in equal quantities.

The second class of engine testing, such as the road testing of an automobile engine or a flight test of an airplane engine, for example, requires more than the ordinary amount of intelligence on the part of the testing engineer. In fact, the personal element entering into such testing is very large. We must frequently rely on the so-called "feel" of an engine to judge whether a certain change represents an improvement or not. It is of course possible to reduce this kind of testing to more or less of a science by the use of instruments such as an accelerometer, recording tachometer, thrustmeter, etc., but in actual practice it is not always feasible to go to the trouble of installing such instruments.

A typical kind of special equipment adapted to testing an internal-combustion engine under actual operating conditions is shown in Fig. 26, which represents a dynamometer car used in testing tractors by the University of Nebraska. The tractor to be tested is coupled to the drawbar shown and is run over a standard course. A varying load can be applied to the dynamometer car and readings are taken of the drawbar pull and speed. The real value is only secured for each of the above methods when they are correlated in a strictly scientific manner.

In bringing this discussion of the internal-combustion engine to a close, I wish to make it clear that I have not attempted to cover the subject in all its phases. What I have tried to do is to bring out important features of design, the why and wherefore of different constructions and my own views on some of the more important questions confronting the designer. In conclusion I wish to emphasize that, enormous as the strides have been in the past in this field of engine design, spurred on by commercial competition at the outset and latterly by the war, there is still far more to be accomplished. In addition to the ever-pressing problems of making the engine more reliable and more economical, less costly and lighter, we are confronted with a fuel situation in the immediate future which threatens to limit the expansion of the industry unless we succeed in meeting the new conditions.

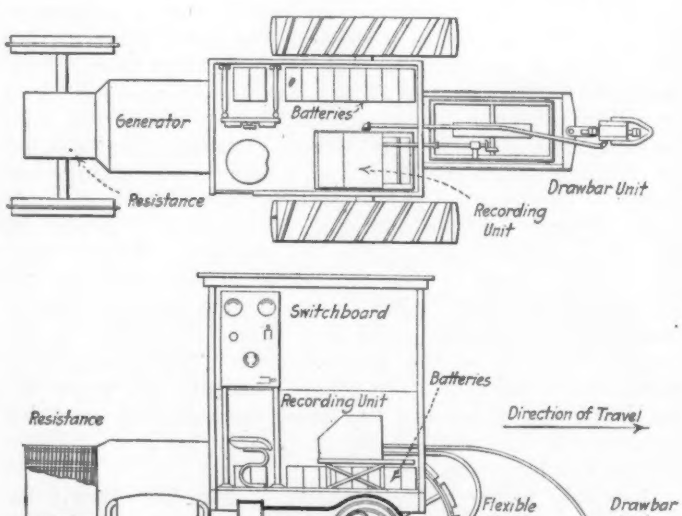


FIG. 26—PLAN AND ELEVATION OF TRACTOR TESTING CAR

THE AIRCRAFT INSURANCE PROBLEM

AIRCRAFT insurance in the field of commercial aeronautics is a fundamental without which civil aviation cannot go far, but on the other hand it is a subject that is approached with much hesitancy by insurance companies. Primarily the greatest difficulty in the United States is the lack of adequate reinsurance facilities commensurate with the capital it is necessary to involve to approach the scale upon which commercial aeronautics can be made successful. This fact alone makes it hard for the insurance companies to attack the problem with a free hand and more especially is it a problem when an attempt to enlarge reinsurance facilities is rebuffed on the ground that the funds are sought to cover a new and untried field of endeavor characterized by the uninitiated as extremely hazardous. This practically announces to aviation that it can stumble ahead unaided and suffer under the cross of tradition and incredulity although the blunders of such a process of bringing out dross have been colossal.

Possibly, however, popular demand for commercial aeronautics in those communities acquainted with its possibilities and present achievements will assist in breaking down such a barrier should it be raised. An organization is already created by this demand known as the Aircraft Coverage Syndicate which is composed of representatives of all the larger insurance companies, amalgamated to unify coverage and secure its proper and reasonable administration and rating. This organization is composed primarily of insurance experts with a few members who have had some experience and knowledge of aeronautic matters although perhaps not to a very detailed technical point. The purpose is excellent and it is felt the willingness and zeal to accomplish this purpose will in all probability permit the insurance field to clasp hands with commercial aviation and strengthen it in its infancy. Naturally this body of men seek assistance and guidance from those whose efforts have led them into daily contact with aeronautics and who have come to be looked upon as conservative and well-balanced judges in their field.

Most of the physical data and statistics however are not of great importance, as they are based on the period of mushroom growth of aeronautics, of war developments and activities and under the stress of such conditions and facts. In fact, about all they do show is that considering the conditions, aviation as a science is comparatively safe, yet there is one point shown which is an old one, the necessary evil of the human element, the pilot. The human element in anything is a large percentage of the risk incident to its execution. In commercial aviation the pilot of the airplane or airship is the responsible pivot around which the general or specific condition and safe operation of the aircraft itself centers. Therefore the pilot or pilots of a company so long as approved and tested aircraft are used are at least for the time being the crucial test in determining aircraft insurance rates.

Most of the insurance companies considering aircraft coverage have through a process of elimination come to this point and have issued pilots' grading cards. It is felt that this step is one in the right direction providing it is properly administered. Col. H. E. Hartney of the Army Air Service has considered in this connection three factors which he believes affect the risk.

(1) Conditions of employment of the pilot
(2) Nature of the pilot's duties and nature of the risk
(3) Length of service

Factors Affecting the Risk

The first can be roughly divided into three divisions where the pilot (*a*) himself owns the aircraft, (*b*) is employed by a company in which he has an interest and (*c*) is employed by a company in which he has no interest. Naturally the case of the pilot-owner is the ideal one from the insurance point of view for the old laws of a man and his own property preclude other than the highest order of caution, attention and care possible under the individual circumstances. It is however not probable that such a status will exist in other than sporting, commuting or private use of aircraft. Passing on to the case of the pilot with an interest we come upon what will be found to be almost the universal case in commercial aeronautics today for this status of employes in any endeavor has been found to be most mutually satisfactory. From the insurance point of view this is the most favorable commercial situation and should be duly considered in rate quotations. The last case of the mere pilot employe is one that will undoubtedly obtain to a considerable extent but it is by far the least desirable from the insurance point of view. Examples of the working of this psychological rule are cases where pilots who handled and crashed Government airplanes later undertook civil operations of their own and developed a decided change toward added carefulness which was openly apparent.

The second factor bears almost an equal weight with the human equation and is a broad field capable of many limitations and qualifications but which should be completely covered in a questionnaire for pilots included with the request for aircraft insurance data. Some of the points to be ascertained are whether or not the piloting is for cross-country work and if so whether the route is an established one or not; whether the flights are to be made over Army itinerary that may be laid down; whether the pilot knows the country over which he will fly very thoroughly; the status and existence of emergency landing fields in the territory or along the route to be traversed and whether the pilot has landed at each and every one of these. A further interesting point is to inquire, hypothetically of course, at first, whether the aptitude of the pilot is sufficient to warrant his being able, should there be a call for it, to fly from his home airport to any of the destinations mentioned in the terms of his contract at an elevation of 50 ft. above the general elevation of the country traversed on the routes. If the pilot has this ability he will be found to have an extremely good sense of location at any time under any circumstances. Finally then inquiring as to the character of the country around the home airport and the extent to which it could be utilized in successful forced landings when taking-off would round out a good general examination on salient points in this phase of the aircraft insurance problem.

A yearly reduction in rate should be possible when the same pilot has successfully accomplished the same route for that length of time. However from the point of view of temperamental and psychological factors it is believed that it will be wise to shift pilots around on the various routes somewhat so as to relieve the monotony. This factor is one to which great consideration should be given for it provides a basis for reaching the point where aviation insurance can be provided as among the regular order of events and yet its breadth of interpretation alone can permit of the problem of personal morale.

It is conservatively estimated that within twenty-five years there will be aerial routes all over the United States and abroad which will be operated entirely without accident and the majority of the people will travel by air due to economic pressure and to obtain the more pleasant surroundings and ease of travel as well as to avoid the greater risk which prevails on railroads, automobiles or other modes of conveyance. At present the greater part of the insurance problem is inappropriately based on and deductions are being made from misleading and irrelevant statistics, comprised of war-time activities and a heterogeneous commercial activity. The real lead for the insurance companies is to accept the fundamentals and extend a helping hand so that aircraft insurance and commercial aeronautics may progress to their mutual benefit and success until such time as each may assume its proper position in the normal order of events.—Air Service News Letter.

Interdepartment Production Contests

By R. R. POTTER[1]

SEMI-ANNUAL MEETING PAPER *Illustrated with* PHOTOGRAPH AND CHART

THE interdepartment production contest has proved notably successful in stimulating what may be called the athletic spirit, or spirit of sporting competition between producing departments. The idea of encouraging competition between the different departments or subdivisions of a manufacturing organization is, of course, not a new one. The simplest form of contest where one producing unit, such as a blast furnace for example, is pitted against another exactly similar unit is familiar to all. It is evident that great advantages will accrue from such a competition. With proper encouragement the interest and enthusiasm of every man in the organization can be aroused, with beneficial results. It is not so obvious, however, that these advantages can be readily extended to practically any manufacturing organization. To make this possible, it is only necessary to establish a simple and definite basis for comparing the volume of output of one unit or department with another; in other words to reduce the production of departments, working perhaps on widely differing components, to what may be termed a "common denominator." It has been found possible to establish such a basis, or common denominator, which is absolutely sound in theory and one which has proved satisfactory by actual trial over a period of many months to the competing foremen in an automobile transmission factory.

The same principle can be as readily applied to almost any line of manufacture, and even to engineering construction work where accurate estimates could be obtained as a basis for comparison. It is applicable especially where the production rate is to be rapidly increased under the same roof or with the same organization, rather than by creating entirely separate new factory units. The general usefulness and applicability of the production contest plan can be appreciated by considering its effect on the foreman, the workman and the management.

EFFECT UPON EMPLOYES

The department foreman in an automotive parts factory can best be controlled by making it to his personal advantage to do exactly the things desired of him by the management. This is a truism which is much easier to express in words than put into practice. Various methods of compensation have been devised, such as piece work, premium and bonus, which are more or less effective in enlisting the full cooperation of the workmen. The foreman's duties, however, are much more complex, and it is not as simple a matter to provide a plan of compensation for him that will serve as a constant and consistent incentive in the right direction.

The foreman may be paid a bonus or premium based on the average bonus earnings, or average efficiency, of his men. This gives an incentive to see that the men working are producing at a high rate on their respective operations, but that is all. It does not directly encourage the foreman to use all the men that could be employed to advantage, to keep all his machines busy, or to see that material passes through his department as quickly as possible instead of being partly processed and then set aside. After all, what is desired is output from the department as a whole, and it is of little avail to have the men on individual machines working efficiently, unless the department as a whole is organized so that their efforts will count. Output on any one operation is of real cash value only when it is made to pass without delay into output from the department.

In some cases, not very common in the automotive parts industry, the output of a department may be all the same kind of piece, all nearly enough alike so that the output from week to week can be fairly measured by the number of pieces or number of pounds produced. In such cases a group bonus may be used based on the output per man in the department, and the foreman may share in this bonus. This is better than the individual bonus, but it offers no direct incentive to the foreman to bring up the output of his department. He may be earning a good group bonus when his department, although working efficiently, is falling behind other departments. The group bonus provides no direct inducement to the foreman to study the balance of equipment in his department, take on extra men, or organize a night-shift if necessary to keep up with the pace set by the other departments. Too often in fact little is thought and less is known by the foreman, or known by the management either for that matter, on the question of which department is in the lead and which is most in need of strengthening. A department which is the weakest by a large margin attracts attention in the long run by getting notoriously behind, and the condition of the different departments is revealed in a general way by the length of their shortage lists, but very few plants are organized so that each department's exact relative standing is brought clearly and forcefully to the attention of its foreman each day.

The production contest plan which I conceived and developed accomplishes this very thing, without the need of any special exertion on the part of the management. If the foreman is paid simply the straight wage or salary, the superintendent or manager must constantly coax, urge or drive in the attempt to keep him up to the mark. If he is paid a bonus based on the output of his men, or better yet on the output from his department, the management is relieved and strengthened to some extent. If in addition to this he is entered in a hot competition with other departments on a basis which he must admit is reasonable, there is further relief to the management and more of its available driving energy can be diverted from the foremen of production departments to the sources for tools, jigs, supplies, and materials.

This diversion will be not only possible but necessary. The foreman, if at all worthy of his opportunity, will take an entirely new interest in his work. It will in fact become a professional sport for him. He becomes a contestant in a game where all can see his success or failure from day to day, and where not only his immediate superior but the men higher up occupy front seats

[1]M. S. A. E.—Production engineer, Fuller & Sons Mfg. Co., Kalamazoo, Mich.

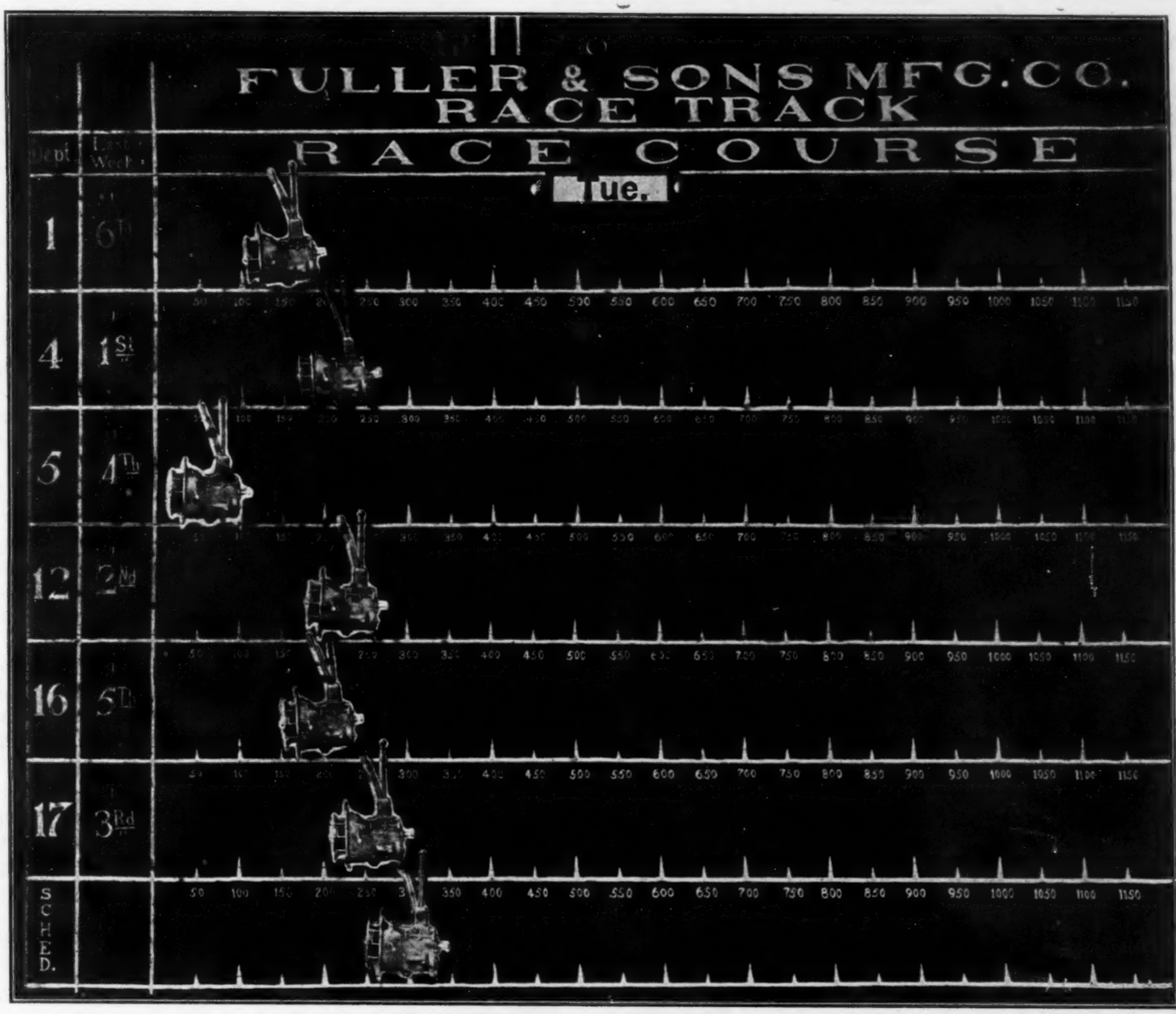


FIG. 1—PRODUCTION CONTEST SCORE BOARD

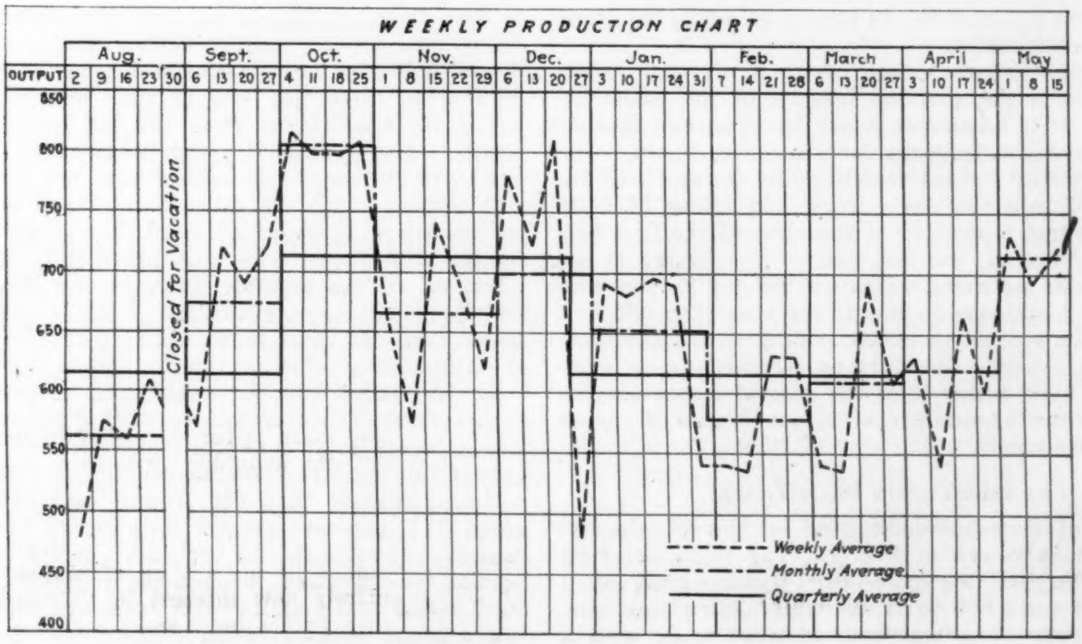


FIG. 2—CURVES SHOWING THE COMBINED AVERAGE OUTPUT OF ALL DEPARTMENTS

in the grandstand. Naturally he will do his best for a big output, and in addition there will be a strong incentive for him to discover and demand correction of weak spots in equipment, methods, factory system or service.

The workman's best efforts are pretty well assured through his own compensation by piece rate, premium or bonus, if capably administered. The production contest in his case simply lends an additional interest, which he shares with his fellow workers. It gives in this way an excellent opportunity for the development of a spirit of teamwork and enthusiasm. A conspicuous and attractive trophy, to be moved each week into the leading department and retained by it as long as it holds the lead, gives the men a tangible object to work for. The extent of their interest depends largely on the ability of the foreman to enlist their cooperation and awaken pride in the supremacy of their department. There is another desirable effect on the workman and foreman relative to the correctness of factory records, which will be explained later.

Value to the Management

To the factory management, the production contest plan becomes not so much an incentive as a source of information. In fact, the plan as used at Fuller & Sons Mfg. Co. was conceived by me while developing an analysis of the balance of output between the various departments. The interdepartment contest makes any unbalance of output from the various departments immediately and conspicuously obvious. Each foreman is trying to put his department in the lead. The management tries to keep all departments even by bringing forward the laggards. The contest plan shows daily which departments are delinquent, and the management is thus given an opportunity to find out the cause and take steps to supply whatever is needed. It is not necessary with this plan to wait until chronic shortages have established themselves in the finished stock storage, to know which department is most in need of help. The output from each department is kept before the management daily in direct comparison with that from other departments. And the success of the management in balancing conditions is measured, as time goes on, by the closeness of the competition.

It is a general characteristic of the production contest that it awakens the sporting interest of the entire organization. It is a common policy to encourage baseball and other organized sports for factory workers. The production contest brings something of the spirit of the baseball field into the day's work. Speaking of baseball, if the game is decided at the close of the first half of the ninth inning, the last half of the inning is not played, because no more scores are needed by the winning team. Analogous to this is the steadying effect of the production contest in never tending to overstimulate any one department. It offers no incentive to do more than just a little better than the nearest competing department. Thus it tends to maintain a balance of output between departments.

The Production Race-Track

The form of score-board designed for the interdepartment contest is shown in Fig. 1. The manufacturing schedule at the time this score-board was designed called for a total of some 800 units per week, comprising nine different models. The race courses were made with a capacity for 1200 units, allowing 50 per cent for overruns and increases of schedule. Each competing department is represented by a cardboard indicator made in the appropriate form of a Fuller transmission. These indicators start off each week at the beginning of the race course and are advanced each morning to correspond with the output of the preceding day, measured in equivalent transmissions. The scheduled output per day is shown by an additional cardboard indicator on the lowest course of the "race track," which serves as a pace-maker.

The "race-track" is mounted on the wall in the factory manager's office. It is visible and readable from his desk and from the desks of the production engineer and the shop superintendent through glass partitions. On a certain Wednesday morning department 17 is well in the lead with nearly 300 transmissions for the first two days of the week. Department 5 is away in the rear with slightly more than 100 transmissions. The other departments are pretty well bunched about half-way between these two extremes. The pace-maker, under the increased schedule, stands at 330 transmissions for the two days. It is a mighty poor start for the week's production. The factory manager and the other factory executives know it. It is kept continually before them every time they glance at the "race-track." They cannot forget it and before the day is over each one will know the reason for that part of this condition for which he is directly responsible. Tomorrow morning each one can see what his efforts today have accomplished.

The foreman of the winning department each week is rewarded with a substantial cash prize, and another cash prize one-half as great is awarded for second place. A large American flag nicely mounted in a glass-covered frame is hung each Monday morning in the winning department. The frame is inscribed "Fuller & Sons Leading Department," and this trophy remains there so long as that department can retain its lead in the race for production supremacy. At the present date no department has been able to hold the flag for more than two weeks in succession, and there is keen rivalry between the foremen to see which can be the first to hold it for three successive weeks.

This form of contest was first introduced at Fuller & Sons Mfg. Co. in August, 1919. The graph shown in Fig. 2 indicates the variation which has taken place from that time up to the date of this writing in the combined average output from the six competing departments. The average for the three months previous to the introduction of this contest was 525 units per week, as nearly as could be estimated. There was therefore an immediate increase of more than 5 per cent in the month of August. This was followed by much greater advances in the monthly averages for September and October. The accomplishment of this rapid increase of production was made much more easily possible through the stimulating effect of the production contest.

In November, specific weaknesses in certain departments were uncovered and corrective measures adopted which began to show effects in December. The average output for the last three months of 1919 was about 15 per cent greater than for August and September and about 33⅓ per cent greater than before the production contest was started. In the first quarter of 1920, production was curtailed through the growing effects of the steel strike compounded with influenza and later with the railroad transportation difficulties. Even with all

DAILY PRODUCTION REPORT.
DEPARTMENT No. 4.

Revised May 1, 1920 Date *May 7*, 1920

Part No.	Schedule	Output Today	Total Labor Hours	
			Per Piece	Today
1042	110	*100*	0.22	*22.00*
1043	66		0.16	
1044	110		0.27	
1045	110	*210*	0.29	*60.90*
1046	66		0.21	
1047	65		0.35	
1048	110	*400*	0.38	*152.00*
1172	65		0.53	
1601	102	*65*	0.52	*33.80*
1602	67		0.39	
1603	67		0.32	
1604	67	*90*	0.30	*27.00*
1605	67		0.17	
1606	67		0.38	
1656	10	*50*	0.56	*28.00*
1665	67	*204*	1.08	*220.32*
1674	67		0.54	
1734	45		0.39	
1739	45		0.44	
1678	10		0.45	

Total labor hours attained today *544.02*

Labor hours required for 165 transmissions per day 520

Labor hours required for one transmission 3.15

Today's output is equivalent to . . . . *173* Transmissions

FIG. 3—DAILY PRODUCTION REPORT

these obstacles, the average for the first quarter of 1920 is no lower than that for August and September, 1919, and a strong recovery is already in sight for the second quarter.

Incidentally it should be noted that the production contest plan furnishes data that can be put on record in graphic form to reveal distinctly the progress or retrogression of each department from week to week and month to month. These data have the unique advantage of being comparable on the same scale between all departments, even though the components manufactured may be widely different in size, kind and value. It is this feature which makes it possible to determine the combined average output of all the competing departments, as shown graphically in Fig. 2.

CONTEST RECORDS AND COMPUTATIONS

The common denominator used as a basis for comparison between the outputs of different departments is derived from the labor-hour value of the different components manufactured. This constitutes the original feature of my method. The labor-hour value is deter-

Date *May 27, 1920*
(Thursday)

INTERDEPARTMENT COMMUNICATION
Avoid Verbal Instructions

To Dept. 1, 3, 4, 5, 9, 12, 16, 17, & 47.
Subject: Daily Production Reports.
Complete work and report on this copy before-

Dept No.	Name of Department	Output Today	Output This Week	Standing This Week
1	Case Dept.	*143*	*465*	*3*
4	Gear Dept.	*168*	*503*	*2*
5	Heat-Treating Dept.	*90*	*371*	*5*
12	Grinding Dept.	*130*	*385*	*4*
16	Bar Stock Dept.	*53*	*528*	*1*
17	Miscellaneous Machine Dept	*110*	*370*	*6*
	Total for Factory	*117*	*433*	

Fig. 4—Daily Production Report Summary

mined from the records of the time-study and cost departments. The proper unit time in decimals of an hour is ascertained from these records for each operation on a given part. The total time for all operations performed on this part in the given department is then obtained by adding together the unit times. This total is the labor-hour value of the part for the department under consideration.

The parts processed in each department are listed on a mimeographed production-report form as shown in Fig. 3. Opposite each part number is placed the quantity of pieces required per day from that department to fulfil the manufacturing schedule. The next column is left blank and in the fourth column is entered the labor-hour value of that particular part for that department.

Multiplying the scheduled quantity in column 2 by the labor-hour value in column 4 gives the number of labor-hours scheduled for that part each day in that department. The summation of such items for all parts listed on the production-report form gives the total value of the output scheduled per day from the department, measured in labor-hours. It is known that this volume of output is required from this department for a schedule of a certain number of complete assembled units per day. Therefore, we have only to divide the scheduled volume of output in labor-hours by the scheduled quantity of complete units to get the labor-hour value per average complete unit for the given department. This value is of course different for each different department.

One of these production reports is made out for each department each day, showing in the third column the quantity of pieces of each kind actually sent out completed. These quantities sent out are multiplied in each case by the labor-hour value of the part, and the products entered in column 5. The total of such products gives the day's output from the department, valued in labor-hours. Dividing this total by the labor-hour value of one complete unit, we have the output measured in equivalent average units, which means that it is measured in equivalent transmissions, engines, axles or complete motor cars, etc., as the case may be. A daily report showing the standing of all departments for the current week is made out in the form shown in Fig. 4. A copy of this report goes to each foreman and to the factory executives daily.

An extension of this plan has recently been put into effect at Fuller & Sons Mfg. Co. by combining the weekly contest with an endurance race over a period of several months. The production from week to week is cumulated for each department and the cumulated totals, from the beginning of the period uptodate, determine the relative standings of the departments. The endurance race is intended to encourage steady and consistent output from week to week, and it also tends to sustain the same added interest that results from the tournament plan in league baseball.

Summary

Enough has been experienced of the interdepartment production-contest plan to show that it is sound in principle and capable of very wide application to industry in general. Its strength lies in its strong appeal to the sporting instinct and pride of competition. Its chief novelty consists in the comparison of output of different components on the basis of equivalent complete units, measured in labor-hours.

An important by-product of this plan is the stimulation of an intelligent and unforced interest on the part of the foremen in the production schedules, records, move-orders, etc. If any part is wrongly listed on the production-report forms, the foreman is quick to discover the error in the unit time or department routing and report it to the planning department.

While not put forward as a panacea for all production ills and ailments, this plan certainly does wonders in awakening the intelligent cooperation of the foremen and in helping to guide the efforts of the factory management in all its branches.

The Trend of Automobile Body Design

By George J. Mercer[1] Metropolitan Section Paper

MY first thought, in connection with the proposal that I present a paper on automobile body designing, was to say that I was too busy to prepare one that would do the subject justice and that I was unable to word it in a manner that I would feel satisfied in presenting. My second consideration was that, as a result of my long experience as a workman and designer and with the additional training I had had, I surely ought to be able to relate my experience and express my thoughts on the subject. This I have done.

A man who spends his days with inanimate things does not acquire the art of speech, yet his knowledge of the subject is first hand. So, when he does talk, some of the things he says are sure to have a practical value based upon experience. My contention has been that the workman does not talk often enough. Therefore, to be logical in my theory, I will present the practical side of the body designer's work and such theories as my experience will allow me to suggest as to the probable trend of automobile body design.

The designer is the man between the office and the shop. He stands in the way of the impatient man who wants action without preparation. The salesman cannot close his contract until the designer gives him a sketch, and the shop cannot go ahead until the production drawings and specifications are made. The designer works overtime when the factory is slack, getting out new design sketches to solicit trade, and then works overtime to get the shop started on the job, but with all his many vicissitudes he is more humanely situated in the large production shops today than at any time previous. There, he has ample assistance; the work is divided so that men become specialists to some extent and it has finally become established that until the drawings are entirely finished there can be no progress made in the factory. It is recognized that to work out the theory of a design in the drafting room will take one man's time only and waste no material, but that to do this in the shop will take several men's time and entail the loss of parts that may be completed before possible errors are discovered. The time and money spent on preparatory work in modern body shops today would hardly be credited by old timers, but this cost when divided among 1000 to 5000 bodies is relatively small.

The functions of the designer in motor-body shops are similar to those of his earlier prototype in the horse-carriage business and most present-day designers received their training in that school. The same fundamental methods are used in designing, except that they have been elaborated in proportion to the greater volume of business and the need for intensive designing to take care of quantity production. In some respects there is greater latitude. For instance, we are not tied down to weight considerations as with the horse carriages. They were made to relieve and help the horse, both in weight and suspension. The almost total elimination of the question of weight was necessary because the stresses and strains on a body are so much greater for motor use that added weight was necessary to get the required strength. It is only a question of time however when the weight of a motor-vehicle body will be almost as important as it was in a carriage.

In the early days of carriage-body designing, the draftsman was not such an important factor as at a later period. In the beginning, each artisan felt a personal responsibility in having his part an artistic creation, as well as being above criticism as a piece of mechanical work. Carriage-body makers have told me that formerly it was customary, when the body was finished and had received the first coat of lead, to have it returned to the body shop while drying so that the man who made it could have the satisfaction of showing his friends what a good piece of workmanship he was capable of turning out. I know of two successful carriage builders who determined the size of a piece of wood or steel for special jobs by simply feeling them. One of these men made a national reputation as a sulky builder and his judgment was wonderfully accurate in determining the sizes of stock on racing sulkies and sleighs. He seldom used a rule; he was guided entirely by his eye and by the feel of the piece of stock in his hand.

At the advent of the automobile, the carriage trade had settled methods of work. The conservative element of that time thought the world was racing to its doom because of the introduction of the coach. The early workers with the automobile were pioneers and enthusiasts. It was the beginning of big business. The coach builder was wedded to his customs and his apathy placed him on the outside of the circle for a time, but the trade could not do without him altogether. The making of a good body design requires a long period of preparation. It is more than the making of mechanical drawings; it is just the right blending of curved surfaces and properly proportioned dimensions of height and width, which makes it a branch of designing distinct in itself.

Development of Body Designing

Body designing has passed through two distinct periods. Since its alliance with the motor-car industry, it is now in its third. The first period was chaotic, through no one's fault in particular. A newer and larger era was in process of development for the body designer and he needed readjustment to fit him for the new life. At about the period that we call the beginning of the motor-car business, the carriage trade was in a fairly prosperous condition and the designing department was a part of every well-established shop. The draftsman was provided with adequate facilities to do his work. In nearly every large city in Europe and also in New York there had been established trade schools, in some cases supported entirely by the trade. These schools had day and evening classes where the young men connected with the industry could learn the art of designing at a very nominal cost.

The greatest inefficiency in the trade, however, was that in the shop the time allowed for working out the design and the shop drawings was too brief to permit of detailing the drawing or working out the development of the curved surfaces, except in the simplest and crudest manner. This condition existed because the

[1]M. S. A. E.—Consulting body engineer, Saxon Motor Car Co., Detroit.

business was almost wholly single-order specially-built work. Each job was slightly different from the others and the price of the product did not warrant more than the smallest amount of experimental work. Many of the shops where good uptodate carriages were built depended entirely upon the foreman of the body shop for the making of these drawing in his spare moments. He was expected to supervise the construction of the work in the wood and blacksmith shops and the assembling, to order the stock for all departments and make the drawings to produce from 50 to 200 jobs per year. He accomplished this by making one working draft do for several jobs, with alterations, and at the end of the year his drawings were no longer records, being so crossed with lines that he himself could not read them. The bad feature of this was that a man so situated became out of touch with the trend of the trade through his intense application and complicated methods. Soon feeling his inefficiency, in self-protection he kept secret as much knowledge of the business as he was able.

This condition caused the second period, when the motor-car manufacturer began to build his own motor bodies, but this soon passed and today we are in the third period. The two interested parties have benefited by their mistakes and are content to work in unison. Body builders have demonstrated that they are able to rise to the occasion and immense shops, independent of the motor-car manufacturer except that they depend upon him for their trade, are operated and produce the required number of bodies daily to meet an equal output of cars.

The Designer's Position and Duties

My theory of the body designer's position is that he must be free to act and his authority as to the advisability of accepting changes in his designs must be unquestioned. He should be allowed to make up his models with only such general instructions as the character of the body requires. He must then combine the methods of the past with those of the present. He must build in his mind and create, fancy free, an artistic conception. This must then be tied down, on paper, to the modern method of developing it for production. The range of possibilities before the designer today is wonderfully enlarged over that of any previous time. The present-day body designer has all of the experience of the past to draw upon for inspiration and the advantage of modern methods plus time and money.

His duties consist of first making the sketch. This is a matter requiring careful thought, because he must be sure that he can build the job later and have it a duplicate of his miniature drawing. He may be called upon for suggestions as to the painting, trimming specifications and appointments. He should at least be in a position to furnish these. The designing of the radiator shape, the engine hood, lamp supports, tire carriers and fenders are part of his work, because all these essentials are correlative with the body design and make or mar the general harmony of the plan as a whole. After the design has been accepted in miniature form, the next operation is to make the drawings for the shop. This is the real test of the designer's ability. The working drawings must carry the effect or characteristics of the small drawings, but they will be different, however carefully the small drawings may have been made. It will be found in every case, when the actual conditions under which the body is to be mounted and made are encountered, that some of the measurements and lines shown on the small design must be changed. This confirms what I mentioned before. The designer must have latitude enough to feel that it is within his province to make such alterations as his best judgment dictates, provided the general effect of the original conception is still carried through. In laying out new effects he must decide as to the shop methods and capacity to as great an extent as is possible. If he is carrying something new to the shop, undoubtedly he will meet with opposition. To overcome this he must be well grounded and confident in his own mind, through his experimental and research efforts, that what he has laid down on paper will be a success. Also, he must be able to demonstrate the practicability of his plans by clean-cut reasoning, so that he will have the working accord of the shop. The best results are obtainable only when the shop has confidence in the engineering department. This is an easy matter to adjust. It is simply the logical outcome of honest work and honest painstaking effort.

Design Factors

The design of the motor-car body, like that of every other commercial article, is based upon some man's thought of what the public needs. Bodies are broadly divided into two classes, the quantity or commercial and the built-to-order, or special job, so-called. From the viewpoint of profit, the special job is a bugaboo of the trade. With practically very little additional effort on the part of the management and some extra work of detailing the drawings for production, a shop can be set for the entire season; but the body end of the motor-car business will always have this condition to contend with to a greater extent than does the balance of the car. The discriminating buyer is the same now as always. It is human nature to wish to have something a little different or more distinctive than that possessed by others, therefore, in the competition to sell, the salesman will force conditions requiring some change in the stock car. That which is most readily accomplished and which is the thing asked for is difference in body styles and, although the salesman may make himself objectionable by disturbing the stock design, he is in reality promoting healthy growth.

The special body is the ideal form of try-out in preparation for new models for the following season. The cost and the workability of the design in production will be the first consideration from the manufacturers' standpoint, but the selling feature will coerce him into giving the public what it wants. In fact, the benefits of a suitable body design are so well recognized from the salesman's point of view that they do not need to be emphasized. That the public demands distinct special-body designs is proved by the number of body shops in every city. Each of these shops make from 25 to 500 special jobs each year. In part, these are bodies to replace those worn-out before the mechanical part of the car becomes unserviceable or that are destroyed by accidents. An owner seldom wishes to replace a stock body from the manufacturer, and many times the stock body is sold for the price of scrap, so that the owner can have the kind of body that he fancies. Body designing in special-job shops is even now quite primitive when compared with large production factories, as far as the drawing goes. The essential points, such as providing for clearance of the wheels at the rear fenders, door clearance at the fender when the door is open and proper seat-room back of the steering wheel, are worked out for safety's sake; but the four views of the side, half back, front and top, are mere outline drawings according to the custom in each particular shop. The workman, however, in going from one shop to another, learns that the more

the drawing is detailed, the quicker he can build the body. This is having the effect of improving the quality and adding to the amount of work that is put upon the shop drawings.

Working drawings that are complete beyond criticism and that contain all the information needed are made only when the quantity of jobs made from one design will warrant the expense. In body drawing, dependence is placed upon the assembly, more than in any other form of engineering work. The working draft is an assembly drawing. It is made full size because the curved surfaces are not true radii. The patterns used for dressing the stock are made from the draft and are checked by laying on the penciled or inked lines, which they must conform to absolutely. The working drawing must be made with the greatest accuracy because the layout man, who takes the drawing after it leaves the table, scales the sizes of stock and dimensions. Very few dimensions are indicated by figures. The paper on which closed bodies are drawn is usually 62 in. wide and the usual length is 14 ft. Muslin-backed paper is best. This is wet and stretched tightly upon a drafting board; when dry it is as tight as a drum head. A base line is drawn the length of the paper about 2 in. up from the bottom; 10-in. squares are then plotted over the entire surface of the sheet and put in with red ink. The reason for this is that any paper will change with changes in the weather. I have experienced a change of $3/8$ in. in the length of a sheet, between wet and dry weather. By working from the 10-in. squares in taking length and height measurements, such variations are minimized. It has become common, recently, to make these drawings on a sheet of aluminum painted white. The lines are first put on with a pencil; when the drawing is finished these lines are inked in different colors for the different views, and the whole sheet is varnished. This method not only obviates the difficulty of paper shrinkage but is a preventative against cutting and tearing; also, changes can be made easily by simply scraping the paint off at any one place. The lines are thus removed and can be replaced as desired. Most draftsmen use a horizontal board for this work. The perpendicular board has the advantage of allowing the use of a more accurate method than that of the T-square and the base of the board for a guide line from which to work, but the flat board is still preferred by most draftsmen because it is more restful to work on and provides an easier position for detail work.

The preliminary work in making a design is to make up a miniature drawing, generally on a scale of 1 in. = 1 ft. This can be either a simple pencil sketch or an ink tracing from which blueprints can be made. Sometimes it is followed by a color sketch. Color sketches are best where possible, as the true proportions of the body and its special features can be better emphasized. Draftsmen do not realize that persons not familiar with drawings cannot visualize the actual reality from simply seeing the lines on paper. It requires training to do this. To take care of this feature and also to make certain that the actual full-size job will be as satisfactory as the sketch, full-size wax models are made.

The initial work on the working draft must be the work of one man and he must be the best man in the drafting room. Less competent help can be used after the general outline is determined. This help is generally limited to two, as they both must work on the same drafting board. The different views are put on the same sheet and some of the views overlap the others. To distinguish them different colored inks are used. Separate detail sheets are used only for the hardware and ironwork and for the die work. The wood framing is not detailed, but the layout man makes a pattern, and samples of the piece if it is curved; this work is assigned a number, just as if a detailed drawing had been made. It is the practice to make a specification sheet at the time the drawing is completed. This is generally lettered on tracing cloth and blueprints of it are made. This sheet carries information that cannot easily be put upon the drawing. It is divided into groups, under different letters or symbols for the different pieces forming these groups; numbers are used also with the symbol letters. The grouping is arranged so that all the component parts forming a manufacturing unit are under one symbol. These will include such parts as are to be purchased, such as locks and hinges for the doors. These will come under the symbol for doors, etc. The final assembly will be grouped under a major symbol, the minor symbols forming its component parts.

The first work in laying out a body design is to determine the extreme dimensions of length, width and height. We must consider the foundation or chassis, the location of the rear wheel in its relation to the dash, the steering wheel location and the shape of the dash, which is really the engine hood at this stage. These points having been located on the drawing, we then determine the desired seat positions according to these set points. The outer dimensions are governed by the thickness of the framing material and the trimming outside of the necessary interior sizes. Having settled upon the greatest width, which will be about in the middle of the body, we lay out two problematical curved lines. One is called the turn-under. The turn-under line indicates the amount that it is intended to narrow the body on each side, from the widest part in the middle toward the bottom. This line is perpendicular and is illustrated by the end view of a door. The other line, called the side sweep, is a horizontal line on the drawing and indicates the amount of gain that has been determined upon, from the widest part toward the back and front ends. This line is laid out at a height corresponding to the top of the doors, if for a closed body, and at the top edge of a touring body. These two lines, the turn-under, or perpendicular, and the side sweep, or horizontal, are the major determining lines used to develop the remainder of the exterior surface of the body. The turn-under line of the rear plays some part, but has not the same importance as the first two. These lines are not true radii in any sense. They are true curves that are made up to pass through certain fixed points that vary with each different drawing, so that the same turn-under or side-sweep patterns are seldom used twice. Standing in the front or rear of a body and at the widest part, the line that defines the perpendicular of the side is the turn-under of the side. The line in the center of the back, as viewed from the side, has the same name. The view of the roof that will be obtained by looking from a high position is the side sweep. In making the draft, the difficulties are not so much the intricacies of the drawing as the tediousness of the work, which requires uninterrupted concentration. Because the work is full size, it constantly requires the draftsman to work from one end of the board to the other, as the different views are necessarily separated. The development of the different parts of the drawing is entirely an application of the rules of geometry to the major curved lines of the turn-under and side sweep. It is necessarily a slow process, because of the size of the work. For instance, the rear corner and wheel-house line, taken from a working draft, show the appearance

of the wood framing of the corner developed so that the layout man can accurately determine the size of stock needed. He can work to actual size and know that this apparently intricate piece of wood will, when finished and put in its place, carry the truly developed outside curved surface. Also, that it will give that pleasing appearance without waste of time, which occurs when these irregular pieces of stock are made by the cut and try method.

The draft when completed is sent to the layout man. He makes the patterns, checks up the methods of framing, marks the numbers on the templets and specifies the number of pieces required. The layout man is always someone that has had real shop training in work that fits him for his duties. He is generally near the drafting room and is always available for advice during the time the work on the drawing is in progress. The layout man is the last bar that is let down before the manufacturing begins. The finished product is the collective effort of the designing and manufacturing departments. It is sometimes stated that good designing is simply the task of getting good work done in the manufacturing, but it is more than this. It is true that the success of the design depends upon its being properly built, and that is the reason the manufacturing end must be ever present in the designer's mind when either sketches or working drafts are being made.

Wax Models

This is accomplished by making a temporary working drawing quickly and accurately, putting on the paper only just enough to make sure that the body maker can go ahead. The body maker for this work must be a first-class mechanic. He sets up all the framing, the seat frames and body boards, and puts locks and hinges on the doors in the same manner as on any custom-built job. Between the framing, where ordinarily the metal panel is used for covering, he fastens wood strips that are about 1 in. wide by 1/4 in. thick and leaves spaces between that are of the same size. The strips are set back from the outer surface of the pillars and framing the same distance. The wax used is a composition prepared for the purpose. It is warmed and applied at about the consistency of thick putty and is shaped with a scraper, a very thin layer being put entirely over all the framing so that the surface is smooth. This is painted, the body is set on a chassis, the fenders are mounted and the radiator and the engine hood are installed. Sometimes the engine hood is faked in the same way as the body, cheap trimming and cushions are used and the whole has the appearance of a completed car. The advantage of this is that additional wax can be added and the shape remodeled as desired. When the design has been approved, the wax is removed, changes are made in the framing, if needed, the entire assembly is covered with metal panels and the result is a quickly-built experimental body.

Regarding the wax model, I wish to dwell on the chances of overestimating present and unduly depreciating past practices. The body drafting room has been compelled to add to its forces and to use any help that could be profitably employed that was efficient in correctly developing curved surfaces. A real designer is something more than a man that is theoretically correct. There is a smug satisfaction that may be deceptive in having made a drawing that cannot be criticised, that is so perfect that all the pieces of stock fit together perfectly and in which no manufacturing mistakes can be detected. As a design it may lack character and artistic feeling. Also, the length of time spent on preparation has been so great that changes cannot be made without going back to the beginning to insure safety in production. The wax model may also serve a sinister purpose in that it is so easy to add wax to it. Someone in authority who has no designing experience may thus impose grotesque innovations simply with the idea of being different. This is probably the reason for some of the odd body designs that have been turned out in quantity production.

Curved-Surface Bodies

All passenger bodies are made with curved surfaces, the reason for this being that more beautiful outlines are produced and these are more especially noticeable when painted. The varnished surface shows to immensely greater advantage when convex. Another reason for curved surfaces is to reduce weight. To be comfortable, the body must be wide and high enough in the middle and at the seats. Below and toward the ends less space is required and the most logical and most beautiful appearance will be obtained by decreasing the dimensions by the use of curved lines.

The credit for creating a system of developing these curved surfaces of the sides, back and top, to produce an harmonious effect and be theoretically correct, belongs to the French. The horse carriage was known as the French rule of body designing, and Paris was the Mecca for many years for the young carriage draftsmen who wished to become proficient. Dupont was the proprietor of a trade journal called *Le Guide de Carrossier.* A young man who had worked in a carriage shop and later worked in a shipyard conceived the idea of applying geometry to carriage bodies, in a manner similar to that by which it was applied to shipbuilding. He suggested this to Dupont and, between Dupont and Brice Thomas, the system of body designing as it applies today was developed. Only in recent years has its use been extended. Previously, each designer absorbed just enough knowledge to qualify, and then trusted to his eye and training for the remainder. Today we make drawings that are actually as well as theoretically correct, regardless of the cost. Work can be begun in advance on the dies for forming the sheet-metal panels. Production is under control simply because our designing methods have been elaborated to take full advantage of the system laid out in the early days of the carriage business, but which was then prohibitive because of the cost. I have emphasized the fact that body builders use sane methods in making drawings today. The question might be asked why this was not done before. Engineering work in all its branches spent money from the beginning on preliminary layout work; it could not have succeeded without it. I can only answer that the body-designing business, whether rightly or wrongly, took to itself some of the eccentricities that are the prerogatives of art, and custom has always permitted art to be illogical.

Presumably, the idea animating all changes in design is to produce a betterment; all changes are not permanent in themselves but are mere stepping stones to further improvements. The manufacturing conditions also change and this will permit, as improvements in methods obtain, to build in quantity work that was shortly previous almost prohibitive. For instance, it was not possible to obtain the fine grade of smooth soft steel that we now have for panel stock a few years ago. Even for hand-made bodies, steel is used to cover the wood framing around the windows in the same manner that aluminum was used a few years ago and which was thought mar-

velous then. Sheet aluminum can be welded now. This eliminates the use of multitudinous moldings to cover the joints. Also, it makes possible the use of narrow panels welded together to cover a large space, such as the roof of a covered body. Sheet steel is now welded on the job when several panels are put in place and fastened; the joints where the sheets meet are welded without destroying the wood framing directly underneath. The irregular surface where the weld is made is wiped with solder and, when painted, it is impossible to detect the joints. Improvements have been made in the hinges, the locks and folding seats, and gasoline tanks are set at the rear in place of being under the front seat; consequently, the whole job is made lower.

Wood Body Frames

In the construction of bodies of all types, it has been a surprise to many who predicted that the use of wood for framing would become obsolete, that the wood frame has remained and that its use seems in no way likely to become less. In some places, such as the rear extension of the runabout, wood is used only for the sill. Some few manufacturers make what they call an all-metal body for touring types and runabouts. More manufacturers would be willing to go into this if body styles were more permanent, but the cost of the tooling up and the die work is greater. Many manufacturers have lost money trying out the all-metal job, only to find that the body so built was costing more than the one with the wood-frame construction. At present, no strong effort is being made to supplant present practice. Wood tends to eliminate the clanging or tinny sound when all-metal doors are slammed against metal posts. Also, wood must be used to some extent for a base upon which to nail the trimming. The wood that is used is not of the same character as was formerly used for carriages. Maple and other cheaper woods have replaced ash.

The use of the Linderman machine, that grooves and glues narrow pieces of stock together, utilizes what in other days went to waste on account of being too narrow by adding other narrow pieces to build up a wide board or plank. This idea is not new. We have had laminated panels for years but, from experience, we have learned that laminated wood must be protected from the weather by gluing canvas over it and painting. The process here mentioned is the process of fitting framing pieces together with a dovetail. The machine does all the work of dovetailing, gluing and joining two pieces of stock together at one operation. The operation is continued on one side of the joined pieces and so on until the required width is obtained. This built-up plank is used for the sills and other framing parts that require wide stock. Criticism of this method of joining several widths of wood together cannot come under any adverse comment as to its durability. It is for many purposes stronger than solid-stock framing, in that the different pieces eliminate or minimize the disadvantages of the cross grain. By using different pieces of wood the average is virtually made equal to that of selected stock and, in practice, wood made up in this manner has given the very best results.

Style and Body Types

Style varies in different parts of the country. It originates in large cities or, if it does not originate there, the stamp of approval is there placed upon it. From thence it travels slowly to the extreme ends of the country. The changes in body designs are generally so rapid that, by the time they reach remote places, they are out-of-date in the centers. A few styles belong to localities, on account of their adaptability to that particular place. For instance, the town limousine, the limousine brougham and the cabriolet, are only sold in the large cities; whereas the small two-passenger enclosed drive, generally termed a coupe, is entirely out of the running as a sales proposition in large cities. It is essentially a country physician's car for all-year use and its sale is confined to usage of this character. These types that are not being used except for specific purposes do not come into consideration on the quantity production basis, their use being too limited for wholesale distribution.

Sometimes body types will undergo changes in some particular part. They still have the same name but present a modified appearance. Changes often occur simply because makers feel that a change is about due and they wish to be leaders. This brings on a general stampede to break away from old lines. Some styles are not suitable for both long and short wheelbase chassis. One thing has been clearly demonstrated, a body style can undergo all forms of modifications and survive, but once it becomes passé, it is killed for all time. Very rarely has this been the fate of a meritorious design. The one exception was the demi-limousine. It would appear that this type will come back under another name and form, because what is designated as the California top is virtually an adaptation of this once proud member of the body family.

We have witnessed a wonderful march onward from the primitive touring bodies with the open spaces between the seats to the uptodate flush body with its slanting windshield and close-curtained top, in which the seat cushions are tipped down at the rear. The rear-seat cushion is more flexible than the front one and the rear-seat back is higher; the front-seat top is minimized to the limit to give a low appearance. We place the extra tires at the rear where weight is needed and tip their upper edge forward so that it has the proper load effect on the car. When tipped back it gives the effect of bouncing off and breaks the iron supports.

One idea that the trade has consistently adhered to as most important has been to give a low appearance to the car. We have seen one objectionable point after another pruned off to attain this result. The modern touring car has about reached low-water mark in this respect. It has low wheels, a high kick-up of the frame at the rear, so as to drop the main foundation of the frame for the body down low, and a low raking steering wheel. These three points, together with that of accentuating the length by having the body line blend continuously with the hood line from the radiator back, have together had a marvelous effect in bringing about the desired result. The touring car is the nearest approach to the universal of any body model. It compares in utility with the horse phaeton. It is not too heavy for general purposes and yet it is ready for expansive duties when called upon. Its low cost and durability make it popular and, while attempts to convert it into an all-year body by the addition of the demountable top have not been very successful on account of their unbecoming appearance, it seems probable that some change of that character is about due. The regular touring top is now being used in its standing position almost entirely in the cities. It is only folded by the majority of users when touring in the country. It is not a folding top in the same sense as was the case a few years ago. Therefore, now that the public has become accustomed to the top as now used, it seems reasonable that some method of

conversion into a quick-change closed job will result. This I think will be the future of this body type. We know that the Springfield solid-roof body with open sides was extremely popular for a time, and but for its mechanical defects would still be in existence. It was really something that the public wanted.

All types of folding-top bodies have been losing out for several seasons. Possibly one of the reasons has been that this country has been the originator of its own designs to an increasing extent of late years. The landaulet and other folding-top bodies are essentially European; the example of the taxicab will serve. At first nothing else but a body that would open up was even considered. Today these ideas have all passed. The standing-top job is more durable, is cheaper to build, and does not become shabby so quickly; it is warmer and more rain proof. The virtues of the folding top are that fine leather has a luxurious appearance when rightly applied in making the upper structure; it also has the advantage of being proof against developing sounds inside, as wood or metal will at times in a closed body. Its rich appearance makes it desirable for exclusive custom-built work, but, all things considered, the folding-top body is losing out on account of its lack of real worth as compared to that of the standing-top closed job.

Concerning the victoria top, this was adapted from the old horse-drawn park carriage. It is by far the daintiest thing that was ever added to a touring body. It is so attractive in appearance that it is and will be used at times, although it has several defects for motor-car work. If made to fall or be lowered, the window lights will be too small to be able to see at the rear, but if it is not made in this way, a large part of its beauty is sacrificed. It is a dust trap and the wind resistance that it offers is very great. One other form of top that did not survive was the disappearing top for open cars. This top folded into a pocket on the sides and rear of the body. It was not possible to make it look well when up, and it soon became obsolete because there was no real need of its continuance.

Returning to the design of the touring-body model, we look for its increase as a five-passenger body rather than in the larger form. The small car is becoming increasingly popular today and the smaller body will naturally follow. There cannot be very many more innovations in changing the character of this design. The most needed and the thing most likely to receive the attention of the designer in regard to this body will be the change in the character of the top; the short wheel-base eliminated the second cowl.

The other type of open body is the runabout. This model has been mistreated to an extent that other designs have escaped. The tendency is for each manufacturer to make this design suitable to his own particular needs and prevailing style does not enter into this design to the same extent as in other models.

Of the closed bodies, we have seen a strong sentiment in favor of the all-year car in this class. At present, we see the passing of the large-size bodies, some of which were like houses on wheels. The only healthy survivor is the sedan. It was the last innovation to appear and it now stands alone as the popular closed car. It had its beginning with the two doors opposite and located for easy entrance to the rear seat, and was equipped with a divided front seat. It was modified to have the doors diagonal, one at the front seat and one at the rear. The general plan now provides four doors and a solid front seat. Even the division making it a two-compartment body has been modified and requests to have the driving seat entirely closed off are seldom made, the single seat being sufficient for general purposes. The other types of popular closed bodies are the coupés and town car types. There are two divisions of the coupés; the small two-passenger car mentioned as being the physician's car, virtually the runabout of the closed bodies, and the four or three-passenger coupé. This is almost a short-coupled sedan, having two doors located at the front and an entrance to the rear seat by an aisle between the front seats. It is suitable for short wheelbase cars and, when used on large chassis, a rear extension similar to that used on a runabout serves to cover the balance of the chassis frame. These three are the sum of quantity-manufactured closed bodies.

The town cars are the cabriolet and the limousine broughams. These designs, as viewed from the stands at the automobile show, are similar to past models. In fact, at this time, when manufacturing is carried on under difficulties and there is a demand in excess of production, it cannot be expected that innovations in body styles will be predominant. Selling competition at present is not competitive enough to urge manufacturers to make radical changes. Not until we have European competition in its old form can we look forward to many body changes.

In the past few years we have seen automobile manufacturers surrender practically all debatable points asked for by body builders. We have seen stock body models multiply until manufacturers have had twelve to fourteen body models, including the convertible types. But since the first years of the industry, we have never had so few stock models and so few radical body innovations as we have today. Viewed from the standpoint of business conditions, this is in no sense a detriment or misfortune; on the contrary, it is a decided advantage, because it enables manufacturers to produce better quality on account of having their efforts more concentrated. Conditions will not be much different until European competition begins in good earnest. When this does come about, we will feel an incentive that does not exist today.

Moderate changes in exterior appearance are going on all the time. This can be illustrated by again calling attention to the sedan. This has continued as a slanting-front job now for over four years. It is an illustration of the feeling manufacturers have when a change is about due. Without any logical reason whatever, there is a strong tendency to shift to a straight-front body and, during the coming year, all new models will be made in this manner. I say there is no logical reason for this, but I will modify that by saying there is no reason for this change on large cars. Short wheelbase cars must have a short steering column to have room for four or five passengers. The slanting front takes up a considerable portion of the cowl length, and we are all striving to have this accentuated as much as possible in length to prevent a stubby appearance. But with or without the slanting windshield front, the sedan is a handsome design. It fills the requirements as an all-year car. In its present form of straight lines it is not likely to undergo any change for a very long time to come, except that the front will be straight. The coupe is due to receive more attention from now on. The four-passenger coupe is very little different from the sedan. It is not so roomy, but it has the advantage of being smaller, and that is a desirable consideration.

The lines of both closed and open bodies are more uniformly straight; in fact, severe lines are the prevailing fashion. More moldings are used on closed bodies at present, because they accentuate the straight-line effect

and permit a form of construction that looks lighter. On a short wheelbase chassis, the long effect of having the lines continuous from the radiator to the back helps the low appearance by accentuating the length.

Town-car models have a limited selling area; therefore they do not come under the classification of quantity production as do the models first mentioned. They are made under conditions that call for more distinct styles and greater variation in design, because they are made by builders that specialize. Being made for the most discriminating buyers, there is an individuality about them that makes it good advertising for manufacturers to have them listed in their catalogs and they add an air of èclat to the trade. They serve the purpose of stimulating designing because, in these models particularly, the buyer can have his own conceptions reproduced and the distinction of individualism will remain his own for a longer period of time.

Fittings and Design Details

Automobile-body designing is a collective effort in which the man who makes the drawings, the men who are responsible for the mechanical part of the work and the purchaser, all have their part. The magnitude of the automobile business continually attracts persons to whom the work is new, but whose previous training has been such that it enables them to break into the business at some point. These new men approach the business from entirely new angles and sometimes do worthy things. Any business that does not hold out attractions of this kind does not make progress. I say this because I know from experience the difficulties that many designers have in keeping uptodate. I can illustrate my meaning by referring to the accessory manufacturers. New operatives are constantly giving their attention to the making of interior mountings, handles, lamps, etc. We can buy them economically today because the volume of business warrants interior mountings that a few years ago were not to be had except when made up specially, at an excessive cost.

Trimming material is another item that in normal times of trade provides a wonderful variety of designs. The use of the word upholstery, as applied to the cloth used on a car, is wrong. Upholstery is a furniture term. Carriage builders say "trimming" in speaking of the material and of the "trimming design" in speaking of the manner in which it is cut and laid out in the body. Trimming designs are made entirely subject to the utility requirements. It is necessary to cut the material into pleats to make a durable form of trimming that will stand up under hard usage. The pleats hold the under filling in place and the material is so shaped to permit cleaning off the dust most easily. The design of the material can carry all the variety that is required. The mountings that comprise the remainder of the utility requirements of the interior part of the body are made mostly in lustreless finish, so as to have the entire view from within restful and in soft harmony. Body designing today is centered in avoiding violent contrasts. What is accepted will remain good form so long as it is the most suitable design for the purpose. We are striving for quiet elegance in all the parts and, when one part is changed, others that are correlated with it undergo changes also.

The fender design on the closed body can be varied considerably in the form of the top sheet, but the shape in which it follows the wheels is now the best that we have ever approached. We cannot do better for appearance or utility purposes on sport models and on specially designed touring cars. The peak fender and the cycle shape are used, together with the step in place of the runboard, but they will be only for such types. Our standard runboard shield and fenders are the fruits of experience and they will remain.

Radiators look best when slightly narrower at the top than at the bottom, as viewed from the front. Rounded corners are used on account of being cheaper to manufacture, but the radius is minimized. The average height above the frame is 24 to 26 in. and the average width is 19 to 24 in. There is a decrease of about ¾ in. on each side toward the top; some have more, but the amount named is a fair statement of what will look well.

The present engine hoods are fairly well designed. In some, the mistake has been made of having the rear end out of balance by being too high as compared with the height at the radiator. When extreme, this makes it appear as if the car were plowing into the ground. A rise of 2 in. should be the maximum between the radiator and the dash, and it is better if this rise is made less for short hoods. The hood louvres are smaller and more numerous; made in this way they lose their conspicuousness and present a blended appearance. To get the desired streamline effect on the side of the body, from the radiator back, we are fortunately able to make a decided gain on each side between the radiator and the dash and do it successfully; no inharmonious effects result, even when this gain is extreme. In body lines, we have three points which we must conform to; two of these are arbitrary and sometimes the third becomes so. These are the width of the radiator, the width of the dash and, in an enclosed body, the necessary clearance for hand room between the steering wheel and the inside of the body framing. That is why, sometimes, and always when the dash is narrow, we have a bumpy appearance on the sides of the cowl between the dash and the front of the door, although this occurrence is less frequent than formerly.

Designs of the Future

We cannot expect to see any change in the interior dimensions of the body. Closed bodies are at least 4 in. lower than they were a few years ago. A distance of 36 in. over the cushion, from the top before it is compressed to the underneath face of the roof, is as low as the average body can be made; in fact, few bodies are made quite so low. The cushion should be 12 to 14 in. from the floor. This height is necessary because, even though the seat can be made like a divan, the difficulty of raising oneself to a standing from a sitting position requires considerable effort, especially for stout people. Therefore, the height inside the body cannot change. Low wheels are being used to get as much of this effect as can be gained. A two-passenger coupe, for example, could be smaller than it is now from back to front and still be all right for comfort but, as the height cannot be trifled with, it must have length to balance this or it will look like a stove pipe.

It is human nature to think that present surroundings with which we are familiar and the era in which we live are preeminent over all past time and possibly a good part of the future, as far as development is concerned, although this is more convincing to those who make a close study of a subject than it is to those who are only casually informed; but even with due allowance for this weakness, it is safe to say that we have a better average in designing and better results, both from the artistic and utility points of view, than we have ever had previously in the motor-car business. Such a point of ex-

cellence has been reached that we will not see any radical changes or radical departures in the form of body designing.

For the next two years we will continue our efforts along the same lines as at present, the keynote being to produce soft straight-line effects. By this I mean that we will not sacrifice the beautiful results that are obtained only by the aid of rounded corners, or the rear end of the body, in the desire to get straight lines. I believe this rounding will be minimized; we will use a smaller radius, but we will avoid that appearance of being just cut off that so often goes with a square rear corner. I am not saying that the square rear corner has not had a beautiful effect when rightly placed, but it must have the right setting; to use it, the body must not be too long. It is a corner that can be used daintily or harshly. With the form I have attempted to explain as being the prevailing type of commercial body, I believe the square window opening will also remain, that the roof will be straight and nearly flat and that the door lines will be square wherever practicable. It is a strange fact that rounded corners on window openings and door bottoms seem to add weight to the appearance. As we are concentrating on lightness in appearance as one of the cardinal principles in our efforts today, my predictions are based upon such deductions. Some lines, particularly the perpendicular line at the rear, are made in practice slightly exaggerated backward, so that they will have an upright appearance when the body is mounted on the chassis. This is one of the optical illusions that are allowed for in bodies.

I have dwelt more upon the position that the designer bears to his surroundings and the nature of his work than the title of this paper would perhaps justify, but I have taken this occasion to explain the body-designing business because I have felt that suspicion was often directed against body designers in that they were thought to be keeping the major part of their work to themselves; in other words, that their methods of working were different from those employed by the other members of the engineering force. Body designing is different and distinct from the other branches of motor-car engineering work. It is difficult to learn because the one feature that makes it an attractive form of occupation is the ability to originate novelties in design, but this comes only after a long process of elimination, oftentimes of many designs, and then from working about until just the right combination is hit. Creative work like this necessarily cannot be communicated to another; therefore, the body designer seems always to be loading himself up with work that he cannot utilize help on, and the mystery that is at times blamed on the body designer is the result of the nature of his business. That the occupation survived and enlisted recruits to carry on the work has been an indication of the tenacity with which the work holds the enthusiasm and interest of those who take it up.

The Discussion

H. M. Crane:—Mr. Mercer's paper is one of the most complete explanations of the relation of design to production, and of the methods of body design, that I have ever heard. I was interested in his description of the horse-drawn sulky designers, who work by eye and by feeling. That same method is necessary in the automobile-body business today. It always has been necessary and is equally necessary in mechanical design. There has been no successful designer who did not have an eye for proportion. It cannot be accomplished by figures. Some feeling that one has is entirely superior to anything that can be figured on paper or with a slide rule. That is true both in chassis and in engine design, but it is much more true in body design. The proportions of the body, if they are wrong, spoil the whole job. It makes no difference how good the painting is, or the trimming, or how handsome the chassis is; if the body is wrongly proportioned, it will never look well.

The sedan has been the coming universal body for the last six years. The automobile is a passenger car. It is a means of transportation and must be so considered. The open touring body with the top up, more or less dilapidated side curtains and a wind shield that always leaks when there is a rain, is no solution of the problem of a proper means of all-weather transportation. The sedan is the transformation of the idea of a touring body with the top up, into a concrete example of a real all-weather design. My experience with it is that it provides everything that is desirable in the way of ventilation and unobstructed view in a car, except when touring in mountainous districts where, of course, the overhead view is obstructed. However, a very small proportion of cars is used that way. Another interesting thing about the sedan is the fact that it is an automobile design. There is very little left in it of the old horse-drawn carriage. The limousine, as we see it today, is still more or less like the brougham that was drawn by horses, but the sedan has superseded that, just as the touring-car chassis has superseded the old high-wheeled design. Another thing is that the sedan was developed and brought to its present beautiful proportions by the custom body builders. A number of sedan models were in existence in 1913 and 1914, when the question of producing such bodies in quantity was only being considered. Several of these designs have been copied very closely in recent production jobs.

The consideration of size in bodies cannot be too largely emphasized. The body is built to serve and accommodate human beings; human beings average a fairly standard size. Many failures in body design have been due to disregarding any consideration of the stature of human beings; for that reason they served no useful purpose. The battleships and cruisers of the Japanese Navy are designed to suit the average size of a Japanese, which is distinctly smaller than that of the European and American. For that reason, the head room is lower between decks, and all parts of the ship are similarly designed. That is exactly what must be done in the automobile body. I have felt for a long time that the appearance of the body has been given preference over provisions for actual comfort. From time to time I have ridden in cars built four or five years ago which were not within 3 to 5 in. as low as the present cars from the ground; there is no question that, on a long trip across country, one will become less tired in such a car than in a car of the present low type. On the other hand, one gets much less excitement, because the difference in the realization of speed is very noticeable. The high-hung car rides better; at 40 m.p.h. it feels very much like the very low cars do at 30 m.p.h., which is only natural. One is riding higher above the ground, and that causes a realization of the speed, so long as one is protected from the wind. It is also true, regarding the height of the body, that the present style of low body certainly looks well; on the other hand, it is difficult to get in and out of. We had a sample there of the type of design that utterly failed to hold in the Van den Plas bodies five or six years ago, in which a very sharp curved roof was used. It had a very snappy look, especially

from in front, but, unfortunately, the driver could scarcely get in and out because the roof was so very low in front. For that reason, and also because it was too extreme, that body went out of fashion.

In reference to the sharp-line design that is so much in evidence today, a few years ago everything was rounded. As a matter of fact, neither of these conditions alone is correct. Mr. Mercer has found it necessary, with the present tendency to sharp hood lines, to retain the rounded rear lines of the body. He is absolutely right. The car that I have been connected with has had a rounded and rather shapeless hood with no style to it; there was nothing to attract the eye. The body was square cornered at the back and had square sides; it had angles wherever they could be put to set off the rest of the job and make it look right. On the other hand, with the sharp-sided hood of the Rolls-Royce or the Packard, a square-cornered rear to a body gives just the reverse effect, it is too much of one thing. In other words, a job must be considered altogether and balanced between the various lines and the various types of design, if a satisfactory result is to be obtained.

The tilted cushion, at least to the extent that it has been carried in many cars, is not an improvement. It folds the unfortunate user up like a jack-knife, and was caused originally by bad riding. The cushion at the normal angle, such as in the passenger cars of railroads, was not sufficient to hold the passenger in place, and he found himself sprawling on the floor on rough pieces of road. On cars that really ride well, there is no necessity for the sharply-tilted cushion. The normal railroad angle is satisfactory to keep the passenger in a comfortable position, and it gives him more positions in which he can sit. With the tilted cushion he must sit back to be comfortable.

W. S. Howard:—I changed from an open car to a closed car because I became tired of trying to put the curtains up in the rain, and of taking them down to see where I was going. The choice of a closed car should depend entirely upon its intended use. I selected a coupe mainly because for a given numbers of passengers a coupe provided more room, not only for the person at the steering wheel but for the other passengers. This coupe had some features that were unsatisfactory, one being the corner post, which interfered with vision. I finally selected a coupe with a bent glass corner, which gave an unobstructed view. I have driven it about 21,000 miles and would not be without it for clear vision. I also approve of the vertical wind shield; it gives fewer reflections than one set at an angle. Anyone accustomed to driving an open car will find that in a closed car there are little lights darting in, and that he must become accustomed to distinguishing between real and imaginary lights. The first coupe I had did not suit me because the rear window did not drop. They are not made that way. I have one now that has this feature. By manipulating the wind shield I can hold a handkerchief in front of my face and it will hang vertically, or, I can hold a handkerchief above my head and it will blow out straight, showing that the air is blowing over my head. Closing the rear window causes a bad draft at the back of one's neck.

The coupe has an advantage over the sedan in providing a greater amount of room. There is more room for four passengers in my car than in any sedan built. There is much more room between the steering wheel and one's body. One need not double up, one's feet can be stretched out and the other passengers have more room. We carry four passengers and have a good spring seat in front. We have a table that is built in, and there is sufficient room for four people to sit around it. The coupe has another advantage over the sedan when touring, because grips and suit cases can be put in the rear compartment and, when in a strange garage or any other place, the car can be closed up and such baggage can be left there, taking only what is needed into the hotel.

I made notes of improvements in that coupe body that might be made. The hardware, while it was the best that could be obtained, is still faulty in that after about 15,000 miles it becomes loose and rattles. To overcome this, I put spring washers back of all the operating handles and also back of the knobs. These spring washers will bend outward, so that they take up all lost motion and make the handles quiet. The silk curtains on the side doors should have protection over them to keep them from soiling when the doors are opened in wet weather. The doors should not have outside flanges, because, on a windy day, the wind will creep in under and blow in quite strongly. Even with large rubber bumpers, the door latches are inclined to get squeaky. By going in back of them and putting in a piece of felt saturated with grease, it will remove the noise, and, by putting a few spring washers under the handles, the result is a quiet body. Nearly all cars have springs on the hood that are too weak. Most of the rattle comes from the hood, because the springs are not strong enough to overcome the vibrations due to rough roads.

R. McA. Lloyd:—Body designs are changing from one decade to another, not only because artists are studying them but because the requirements of the users and the available material are changing. I believe in the sedan type of body. It is the most ideal for all present purposes. It will not continue indefinitely, because new requirements will arise and other conditions of available material may change the designs again.

There was a cab company in Paris twenty-five years ago, called the "Petit Vaiture," which built the smallest possible cab; they made them as light as possible so that the smallest of horses could be used with these cabs. In that way, they were able to make money at the same rate of cab fare on which other companies were losing money. As gasoline is increasing in price and we are not certain of the future supply, it may be necessary to produce an automobile that will meet the needs of the people and that will not be so heavy. A car for everyday use does not require room enough for seven, when only one passenger is usually in it; and it may not be necessary to provide for comforts, such as ventilation and other things, which are all very nice but which add weight. We may have to produce something in the way of a very small body which would be more economical than the big sedan, and we may be forced to have the driver stay out in the weather, to save gasoline. The conditions of the fuel supply certainly will have some influence on the future of body design, because the weight of the body at present has great influence on the chassis and the power required to drive it. I think that while we can rest for a time on the improvements in design in the sedan, we must always look forward to the advancement which will become necessary in the future.

Herbert Chase:—Regarding the matter of adapting aircraft practice to body construction, as far as fuselage construction is concerned, is it possible to utilize laminated wood construction to a considerable extent with a view to decreasing weight? Also, is it possible that in the future, in an effort to decrease weight, the body structure will be made so as to constitute the chassis frame, the body thus becoming the chassis frame and

supporting without separate framework the engine and driving mechanism?

GEORGE J. MERCER:—At present, bodies require so much strength because of the iron work in them and because the top must be built up and supported by pillars, that it is about as economical to use steel as to use the laminated wood construction. Laminated wood would save some weight and probably there will be a tendency to work toward that, but it appears that we will not consider it for several years.

E. FAVARY:—There is a decided advantage in the tilted seat if a low-body effect is sought. Suppose the floor body is to be of a certain height for minimum road clearance, and that the seat is to be very low. It is natural that by tilting the seat more room for one's knees and legs can be obtained than if the seat were perfectly straight. This has been done in motorcycle and cyclecar bodies to obtain a low body and greater comfort. Would Mr. Mercer recommend this for automobile bodies?

MR. MERCER:—It is the practice at present to give less slant to the seats than formerly. Mr. Crane's view of it is perfectly correct; it was over-done, and it is not a good seat to rise from because the position is unnatural. The weight of the body is so far back that it is difficult to regain a standing position. Formerly, seats tilted about $2\frac{1}{2}$ to 3 in. were common, but today stock bodies do not have more than a 1-in. tilt.

H. C. GIBSON:—The fundamentals of the automobile require a certain amount of strength for maintaining the structure and resisting road shocks. Using the illustration that Mr. Mercer gave of the structure of ships, it appears that it is a very short step from the use of two individual structures, such as the chassis and the body, each strong enough for its purpose, to the principle of the ship, which is in itself a house, a carrier, and a structure strong enough to withstand stresses brought about by the sea, such being far greater than those brought about by road effects. So it may be possible to take the present day, pressed-steel body structure, for that is what it amounts to, and arrange for hanging within it the parts necessary for the support of the driving and rolling mechanism.

MR. MERCER:—I referred in my paper to the fact that manufacturers would elaborate more on their structural formation. I also spoke of the all-metal body and said that more manufacturers would use it, provided that styles were more permanent. In answer to another question that I believe relates to the same thing, by the use of steel the body is so much more quickly painted and is produced so much quicker, that this is one of the reasons we will not use laminated wood in the near future. Since laminated wood is made up of thin layers, the nature of the wood is killed. It has an absorbent quality that keeps on drawing in, and the painted finished surface is really never good. The time may come when some form of body may be originated, possibly an adaptation of the sedan, in which we can use some of the steel structure by running the chassis frame up, or at least a part of the chassis frame. The possibilities that it can be assembled in that way are very great, but not at present. Bodies are manufactured for sale at a profit, and a profit is being made as they are built at present.

A. M. WOLF:—A framework into which the chassis units could be set, so to say, would not be a suitable solution. We must think of production, of the effect of such an assembly when we come to paint the body, when we install the engine and when we expect to finish each unit. If each unit is finished before being assembled, there will be much work to be repainted. But it is possible to combine a chassis frame with a body frame, so that they can be independently mounted and one will reinforce the other. In that way the assembling would be distinct in each case, and there would be no interference.

The necessary relation between the fenders, the splashers and the top, with the lines of the body, cannot be over-estimated; it even includes the wheels. Many present-day cars have disk wheels, cars probably mounted high above the ground, in which the whole effect is anything but pleasing. To have a car body and the other lines conform with the wheels, requires that thought be given to the whole car as a unit. So far as the engineer is concerned, aside from the body builder and the body draftsman, many of the present hoods have probably more louvres in them than are necessary. I believe that few cars have been tested to find out whether all these louvres are beneficial. I have seen cases where the fan is drawing in air through the foremost louvres instead of pulling it in through the radiator. This is tested easily by placing a piece of tissue paper at the front openings; very often the draft is into the hood, instead of out of the hood. In other words, we may be sacrificing fan efficiency, or the drawing of air through the radiator, for the sake of appearance.

In regard to the construction of the frame itself, we have the exposure of the frame at the front and the rear. I believe the Packard company was one of the first to use a full apron extending down from the crown sheet of the fender to the side rail, in combination with a radiator apron or splash apron under the radiator, in such a way that the goose-necks of the frame and the springs are entirely covered. I believe that this has the most pleasing effect, although we still see cars that have these members exposed. The same thing applies to the rear end of the frame. The rear end of the frame is a thing that we have all neglected. We place the extra tires there, perhaps a trunk, and then dispose of all the things not desired in front or at the sides and put them at the rear. Several attempts have been made to cover the unsightly gasoline tank in the rear, by putting an apron over the top of the frame to hide it, or by making the rear cross member hide and support it. On the new National car, an apron similar to the front radiator apron is placed at the back of the frame, to come between the goose-neck and extending down from the body.

There seems to be a tendency toward having a clean exterior for a car. We have done away with the extra tires at the side, and with the battery-box. The running board has been cleaned up and there also is a tendency now to eliminate the running board itself. This is best exemplified by the Cunningham car with the small steps. There are limitations to such a construction depending upon whether it is a custom-made job or a small car quantity proposition, but, from the customer's point of view, to attain the greatest elegance, the cleaner the exterior is the better it will appear. That will be, I believe, the future solution. The same argument applies to the rear of the car. One looks at a car that appears beautiful from the front or side, but from the rear not only do the ungainly goose-necks project but the tires are mounted at a very ugly angle; they seem apart from the car and to have no relation to it. The future car will have the extra tires out of sight, but how this is to be done is a problem. The displeasing effect of having the top drop into a container has been mentioned. The effect is probably not pleasing in a five or seven-passen-

ger car, but it seems that in smaller cars, such as four-passenger cars, with their narrower cushion width, that a pocket can be provided for the top to drop into, and that the lines of the body most prominently visible can be kept in their proper relation.

If either the curves or the straight lines are exaggerated, it causes trouble. With too many curves, there seems to be no character to the body; with too many straight lines, there is harshness. A suitable combination of the two is required to make the right body. I believe that bodies will never come down to what might be called a standard form, unless a utility car is developed. Bodies will vary more or less, as styles vary in other instances. We cannot lay down any one fundamental body. An automobile body is a work of art, and art cannot be standardized.

Mr. Gibson:—The only objection that has been raised so far to a proposal that the chassis and body be combined is that it might be difficult to assemble. It has already been said that the body designer finds it difficult to sell his idea to the production manager. So far as assembling difficulties go, before cars were assembled the way they are, no one would have credited a manufacturer with the possibility of making a profit after the method of assembling. As to painting, with the very economical car suggested by Mr. Lloyd, it could be painted by dipping it. That may seem ridiculous, but I am only pointing out by this that there is no real difficulty if there is a real advantage in lightening and strengthening the car, and so reducing its cost and increasing its efficiency.

Mr. Crane:—The door openings present one fundamental difficulty in realizing any great advantage from Mr. Gibson's idea. If we could have bodies built like those of some testing bodies, in which one steps over a rail about 2 ft. high to enter the car, there would be a very great possible advantage in combining the body and the frame. But, with the door openings cut clear down to the floor and with the light roofs essential to a closed car, there is almost no chance of adding to the strength by utilizing the body structure.

As to plywood, what I have seen of it makes me think it the worst thing possible to use on a body. I have seen it used in a great many aeroplanes, and I have never seen one that has retained a smooth surface for any length of time. Plywood seems prone to go into waves. We know what that looks like when it is varnished; it is bad enough on a dull painting job. It is but slightly if any lighter than the wood panels that were used in the bodies, built entirely of wood which, barring their cost, were undoubtedly the best bodies that were ever built, because of the unit structure of the completed assembly. The composite job of wood and steel has never been as good as the complete wooden job. That has been proved often in marine work. There is also the difficulty of maintaining in a really durable condition a body depending upon so much glue; and also there is the difficulty of stiffness. Many designers fail in automobile work, both in chassis and body work because they plan simply to have a thing strong enough, when practically all the difficulty is to make things stiff enough. Much high-grade material has been used in attempts to make things strong enough, when the requirement of stiffness was such that the lowest grade of material could have been used. We learned that in our experience with crankshafts. That is practically true in body work also, where glass windows must be used that will withstand doors being slammed by careless persons. In spite of all the care used in the design of some of the large bodies, one of the custom builders insisted on making the larger glasses in two sections, split in the middle to eliminate breaking. On the other hand, a very commendable improvement has been made in chassis construction, to take care of what the body builders formerly had to consider. The Cadillac chassis is a very good example of that. It is a very fine structure mechanically and in design. It preserves stiffness in every direction. By putting 50 lb. on the chassis, anything up to 200 lb. has been taken off the body for an equally durable result. The Marmon is another case where about all the available structure has been used in stiffening the job. We will undoubtedly progress in that direction, as the chassis designs become more stable and manufacturers are able to use more expensive tool equipment to accomplish the result which is so greatly to be desired.

Mr. Mercer:—With regard to the present type of body and having the rear window in closed bodies opened, it has always seemed strange that something has not been devised to obviate the back draft in a touring body. The reason that the rear windows on closed cars are not dropped is because the back draft has a tendency to bring dust back into the car. Years ago all windows were dropped. This practice was abandoned because the dust will roll up as the car passes over the ground and will come inside. At the time that change was made the closed-type body was not so popular. It was more of the limousine type, where the driver is outside and the front window is not open. Having the front window open makes much difference, but even on touring bodies, particularly those having a wind shield on the back of the front seat, the back draft is severe. Something needs to be done to control that wind, either by carrying it out at the top or down at the bottom.

PROPERTIES OF SPECIAL TYPES OF RADIATORS

REPORT No. 86, of the National Advisory Committee for Aeronautics, which has just been issued, discusses the general performance characteristics of three special classes of radiators: those with flat plate water tubes, fin and tube types and types that whistle in an airstream. Curves and tables show the performance of representative radiators of each class and compare the flat plate and whistling types. Empirical equations are given for estimating the performance of flat plate radiators of various dimensions.

The report, a copy of which can be obtained upon request from the National Advisory Committee for Aeronautics, Washington, also contains a brief discussion with curves showing the effect which yawing of the aircraft has on the properties of the radiator.

APPLICATIONS FOR WATER POWER

THE Federal Power Commission which will administer the new Water Power Act has received applications for more than 500,000 hp. despite the fact that the Commission's machinery has not yet been established. The Commission is made up of Secretary Baker, Secretary Payne and Secretary Meredith. O. C. Merrill, ex-chief engineer of the Forest Service, has been named executive secretary of the Commission.

Ottawa Beach Plowing-Speed Tests

IN connection with the Summer Meeting of the Society which was held at Ottawa Beach, Mich., in June a number of tests were conducted. Among these was a series to determine the most desirable tractor speed for plowing. D. L. Arnold, chief engineer of special engineering, International Harvester Co., Chicago, has prepared a report of these tests which is given below together with a description of a special dynamometer car that has been developed for testing tractors.

FIG. 1—THE TRACTOR AND THE DYNAMOMETER USED IN THE TESTS

REPORT OF TESTS

The plowing-speed tests were conducted in very loose sandy soil with a light sod top on which there was a trash of weeds 4 to 8 in. high. The tenacity of this soil was very poor and when disturbed by plowing the least wind would raise a dense cloud of dust.

To eliminate any error due to insufficient traction a 5-ton Holt caterpillar tractor was used. This machine was extremely advantageous as it permitted a range in speeds from ½ to 6 m.p.h. A three-furrow high-speed plow with 14-in. bottoms and two other standard makes, a three-furrow with 14-in. speed bottoms and a two-furrow with 14-in. Scotch clipper bottoms were used.

FIG. 2—A REAR VIEW OF THE TEST APPARATUS

In all of the tests it was endeavored to hold the depth constant at 7 in. and simply to vary the speed of plowing within the ranges available. The percentage of variation from this depth was small.

This type of soil once plowed needed no further preparation; thus those speeds that left the finished ground level produced the best after results. The lower speeds left the soil in well-crowned furrows, while the higher speeds threw the ground so much as to make a ragged looking field. In Mr. Arnold's judgment, disregarding the horsepower consumed, the speeds from 3 to 4½ m.p.h. left the ground in the best shape. Utmost care must be used in operating at high speeds as hidden obstacles often wreck the plows.

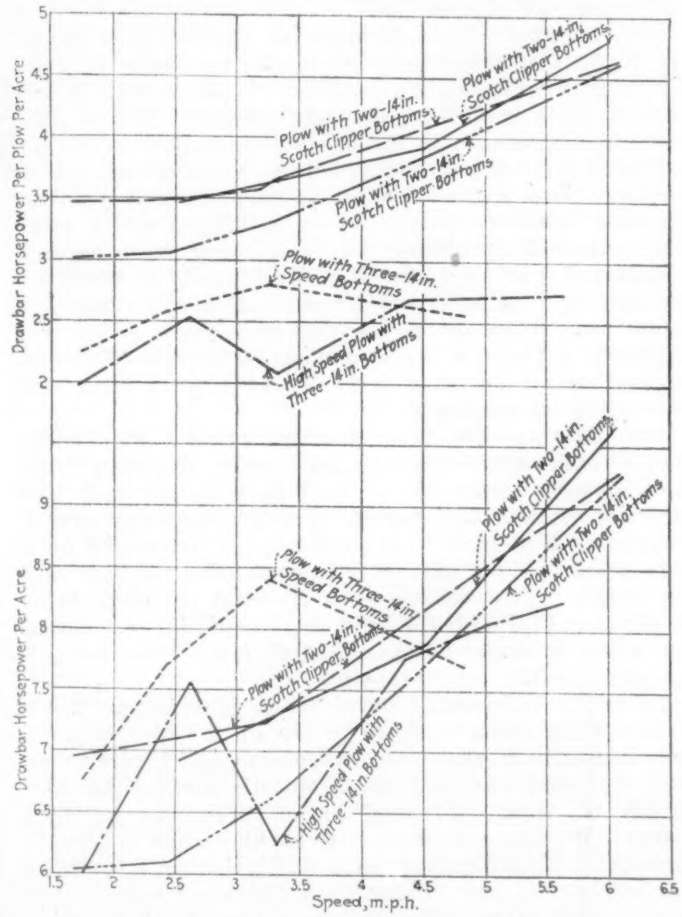


FIG. 3—RESULTS OF THE DIFFERENT TESTS

Figs. 1 and 2 show the apparatus used. Fig. 3 is a comparison of the results obtained on all outfits, as far as horsepower required per acre is concerned. With Scotch clipper bottoms an increase in the drawbar horsepower was noted. With the increase in speed and with the high-speed plows the increase in horsepower required up to 3 to 4 m.p.h. and the decrease in power required thereafter should be noticed. These speeds held true for both types of speed plows.

It is also well to note that in these tests the two-furrow Scotch clipper bottom plow consistently re-

quired for its operation more horsepower per plow per acre than did either of the speed plows.

The Dynamometer Car

With the increase of power farming, the tractor or other means of mechanical power is being used to operate all agricultural implements and the shortage of man power has made it necessary that maximum results be obtained from the man power expended, and further, the initial investment in equipment must be kept at a minimum. Thus the natural trend has been to speed up operations with more or less detrimental effects to present machinery. Realizing the seriousness of this situation with the innumerable variables that enter into it the International Harvester Co. has found it advisable to establish, if possible, the true facts governing these variables and thereby arrive at an economic solution.

A dynamometer car was therefore built to determine

(1) Horsepower at the drawbar
(2) Horsepower at the belt
(3) Slippage of the driving members
(4) Efficiency of different lug equipment under different conditions
(5) Fuel economy under widely different conditions
(6) The effect of grade and soil condition on drawbar horsepower
(7) Belt slippage under various conditions

Upon a tractor chassis, including the transmission, was built a steel body as shown in Fig. 4. This body is well ventilated, has ample light provided by large windows which may be removed in extremely hot weather and which are covered with metal shields when

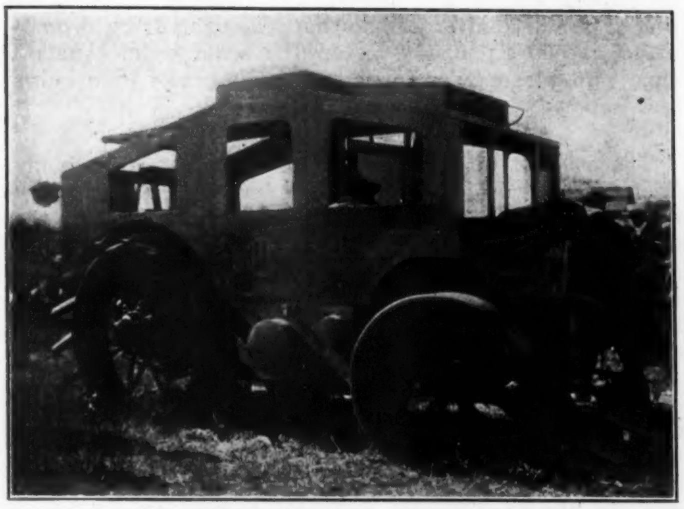


Fig. 4—The Dynamometer Car

the car is not in use. A seating capacity for six persons is provided so that any test may be witnessed by those interested.

Some of the general dimensions are as follows:

Length over all, ft.	$13\frac{3}{4}$
Height over all, ft.	$7\frac{3}{4}$
Width of front wheels, in.	$11\frac{1}{4}$
Diameter of front wheels, in.	$38\frac{1}{4}$
Width of rear wheels, in.	12
Diameter of rear wheels, in.	50
Wheelbase, ft.	$8\frac{1}{4}$
Weight, lb.	7,500

A Gulley dynamometer is used for recording the data and is mounted in the car as shown in Fig. 5. The arrangement of the mechanism has been slightly changed

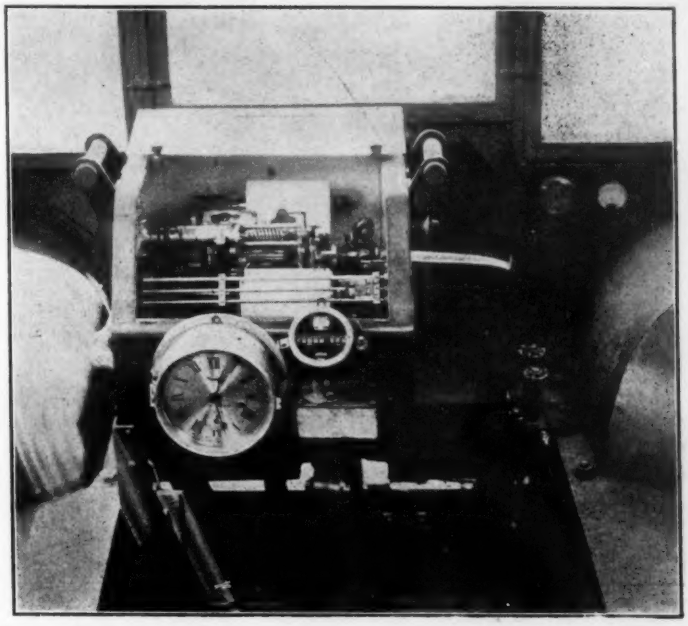


Fig. 5—The Recording Dynamometer Mounted in the Car

to suit the conditions of mounting and there were added to the recording mechanism the necessary pencils for recording the revolutions of each driving member and the depth of the inside and outside plows when the recorder is mounted on the plow attachment. A speedometer was added for giving the instantaneous speed traveled, the integrating pencil was eliminated and is now used to record the slippage of the measuring wheel and a quick method of changing the rate of paper travel was also added. There is yet to be added a means for recording the grade as well as the indicated horsepower of the engine.

The recording instrument as above described is operated by a flexible shaft attached to the right front

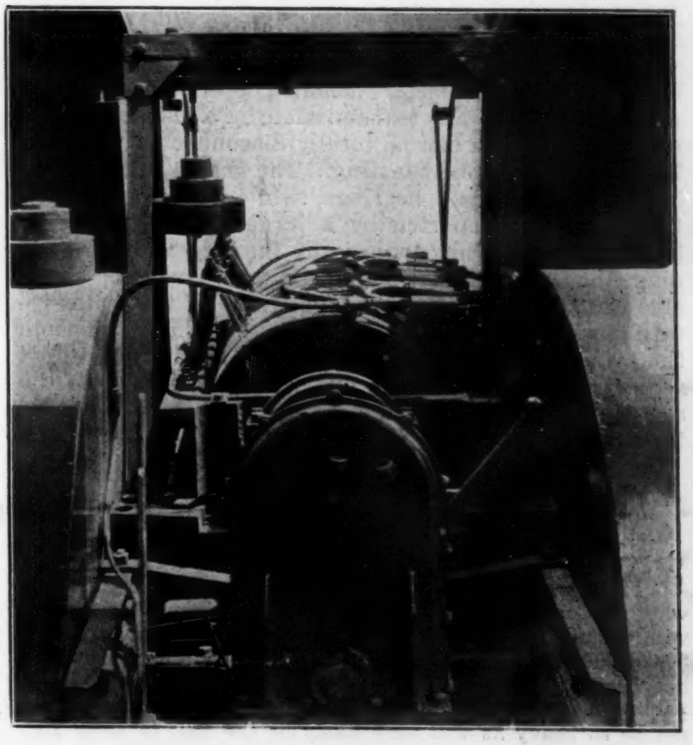


Fig. 6—The Mechanism of the Dynamometer

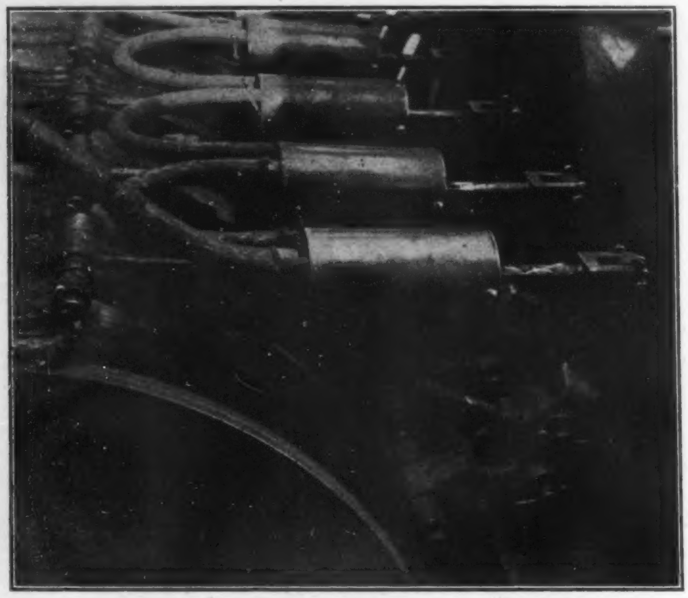


FIG. 7—THE AUTOMATIC COMPENSATING DEVICE EMPLOYED TO STEADY THE LOAD

wheel, which is 10 ft. in circumference. The paper in the recording instrument has two speeds, so that 1 in. of paper equals 25 or 50 ft. of ground travel. For drawbar tests the tractor under consideration is connected to the dynamometer car, with a Gulley hydraulic cylinder between them. The pull is exerted on this cylinder and the resultant pressure is transferred through a flexible tube to a Tabor gas engine indicator, the indicator pencil recording on the paper the amount of pull. The paper advances according to the distance traveled. Means for vertically adjusting the dynamometer drawbar at 1½-in. intervals are provided and a large range of drawbar heights may be used as conditions demand. This drawbar connection is swiveled and connected to the steering gear so that the car will readily follow the tractor.

The desired load upon the tractor in excess of the weight of the car is established by the prony brake cradle-type dynamometer mounted over the rear axle and connected to the transmission by a suitable clutch mechanism which can be totally disconnected when the brake is used for belt testing. The cradle of the brake is supported in ball bearings, while the drum within the cradle is supported by a large shaft running on ball bearings. This drum is 30 in. long and 16 in. in diameter and is water-cooled by two tanks on either side of the car. The centrifugal force of the water rotating within the drum causes it to circulate through the tanks, the piping being arranged so that the effort required to circulate this water is transferred to the cradle and measured by the scale, all of which is shown in Fig. 6.

The desired load is applied to the tractor by increasing the tension on the eight brake-bands surrounding the drum and attached to the cradle. These bands are contracted by the air pressure applied to the cylinders, this pressure being controlled by valves shown at the right of Fig. 4; the first wheel valve is allowed to leak sufficient air so that the right pressure at the cylinders is obtained for any load. The foremost valve is for relieving slight excesses of pressure quickly without disturbing the setting of the other valves, thus holding the desired load. In case it is desired to throw the load off suddenly the valve at the left is quickly opened and relieves the pressure at the brake without relieving the pressure in the supply line, and the load can be suddenly applied by quickly closing this valve.

The steadiness of the load is insured by the automatic compensating device shown in Fig. 7, this particular arrangement being such that the brake bands are prevented from grabbing due to any sudden changes that occur in the friction between the drum and the band lining. This insures an extremely steady brake and one in which it is possible with very little attention to hold the scale beam in the center of its range which is especially advantageous for belt testing. There is also a drawbar at the back of the car that can be used for attaching an additional fixed load if so desired. On good footing about 500 lb. is required to pull this car at 4 m.p.h., and therefore a large range of tractors can be handled.

In belt testing the clutch between the drum and the transmission is totally disengaged and the tractor is belted to the pulley on the dynamometer shaft. Changing the size of pulleys used enables the dynamometer to handle almost any horsepower desired. The drum and scales are calibrated so that when the drum is operating at 500 r.p.m., 10 lb. on the scale beam equals 1 hp. The horsepower formula for the brake then being

$$\text{Hp.} = \frac{\text{load in lb.} \times \text{r.p.m. of drum}}{500 \times 10}$$

There is yet to be added to this machine an inclinometer for recording the change in grade, the necessary apparatus for recording the indicated horsepower of the unit under consideration, a horsepower meter for graphically recording the belt output at all times, a similar graphic recorder of the fuel used, speed counters and indicators for the brake drum and engine, the necessary electrical apparatus for operating the stop watch and the recording mechanism, at the beginning and the end of the tests. Also there will eventually be added the necessary temperature and barometric pressure devices.

The recording mechanism of the dynamometer car can readily be removed and attached to the plow or other drawbar equipment in order that data may be secured relative to the facts governing their operation. This was done in the Ottawa Beach tests. (See Figs. 1 and 2.)

FIVE MILLION DOLLARS FOR CANADIAN HIGHWAYS

FIVE million dollars will be spent this year through Federal and provincial grants in improving the main highways of Canada. Of this amount the Dominion Government will contribute $2,000,000 and the provincial governments $3,000,000. This is the first year in which the road money has been available, and in view of the time taken in preparing plans the initial year's outlays, it is expected, will not be so heavy as will very likely be the case in some succeeding years.

The improvement scheme, however, is general. Before the Dominion Government makes any grant for the purpose the Provinces have to file general plans, and every one of them, from coast to coast, has done so already. The detailed plans also need approval by the Dominion Government, and this has been done in several instances and work is under way. While the Provinces may improve whatever roads they choose to, the Dominion grant of 40 per cent of the cost is restricted to main or trunk highways.—*Monetary Times*, Toronto.

Advantages of Magneto Ignition

By A. D. T. LIBBY[1]

CLEVELAND SECTION PAPER *Illustrated with* DRAWINGS AND PHOTOGRAPHS

A DISCUSSION of the advantages of magneto ignition resolves itself into a comparison of magneto and battery-ignition systems, resembling the early discussions of the relative merits of the direct and the alternating-current electric systems; both of which are in existence and fulfilling their respective parts in the commercial world today. Undoubtedly both the magneto and the battery-ignition systems will be used in the future in a somewhat similar manner.

Ignition is closely related to carburetion; therefore this discussion will touch upon that subject. That successful carburetion is based on getting into the engine cylinder the best explosive mixture possible, is certainly not open to argument. We know that it is exceedingly difficult to introduce a perfect mixture into an engine cylinder. It is an elusive combination and at present an almost hypothetical figure; something to think and dream about with the hope that success may some day be possible. Just how much vaporizing the present-day carbureter does is difficult to state. Without casting any reflection on carbureters, it appears to me that some of them act merely as mixing devices, particularly at the time of starting and in cold weather. During such periods the hydrocarbon fuel is broken into a molecular state and carried along with the air into the engine cylinders, provided that the molecules do not hit the intake-manifold walls and become deposited thereon before they can reach the engine cylinders. Carbureters are therefore designed with many different styles of jets, all for the purpose of getting a suitable mixture into the engine cylinders. We are told that some present-day fuels are so constituted that the unruly atoms cause knocking, and we are told also that this knock is due to the shape of the engine cylinders and not to the fuel. Assuming that both statements are partly right, the question of carburetion of present-day fuels is closely intermingled with the question of means for igniting these conglomerate fuel mixtures.

If at the time the spark takes place at the spark-plug the mixture around the electrodes is wet, as is bound to happen in starting and particularly so in cold weather, and if there is not, relatively speaking, considerable heat in the spark, the mixture will not be ignited. If the spark carries heat enough, the molecules may be actually vaporized and ignited and the engine started with little loss of time. I have both magneto and battery ignition on my car. The battery system is as good as any single-spark system on the market today. I have repeatedly made starting tests with the hand-crank as well as with the starting motor; the magneto will invariably beat the battery ignition under both conditions of cranking. The magneto used is capable of delivering sparks at low rotative speeds, with no impulse coupling.

FUNDAMENTALS OF IGNITION SYSTEMS

In the consideration of ignition systems certain fundamentals should be kept in mind: (*a*) that engine performance is influenced greatly by the manner in which the pressure in the cylinder rises after the spark passes; and that this depends upon the timing of the passage of the spark, with reference to the position of the piston and the velocity of flame propagation through the mixture in the engine cylinders; and (*b*) that flame propagation depends upon the kind of mixture; a very rich or a very lean mixture burns slowly, with the development of but little power. In this connection, Prof. O. C. Berry, of Purdue University, in his paper on the Mixture Requirements of Automobile Engines,[2] emphasizes the fact that highest volumetric efficiency and maximum power are obtained by the coldest mixture that can be carbureted. Such a mixture, however, leads to condensation in the engine cylinders. The condensed fuel works past the pistons into the engine crankcase and dilutes the lubricating oil. One well-known engineer using battery ignition states that a wet mixture causes the high-tension current to leak over the surfaces of the spark-plugs, instead of arcing the gap, and that he has been working on an extensive heater system to get a dry mixture, ostensibly to get one that will prevent dilution of the crankcase lubricating oil and one that the ignition system can fire.

Any ignition system is more or less dependent upon the spark-plugs. The passage of the spark is affected by the shape of the electrode, to some extent by its material, by the polarity of the central electrode, the pressure around it, the velocity of the particles of the mixture, the temperature of the mixture, the temperature of the electrode and the quality of the insulating material. An interesting article by Dr. R. H. Cunningham[3] shows the leakage of spark-plugs under the influence of heat, such as exists in an engine cylinder. This leakage is increased by the presence of the wet fuel film already mentioned, as well as by oil leakage past the piston. In addition to the leakage current at the spark-plugs, there is a further loss of ignition current due to the leakage in the high-tension cables, as well as in the current required to charge them, they being capable of absorbing a considerable portion of the secondary current in the same manner that a condenser acquires a charge. Hence, the source of the ignition current should be of a character sufficient to

(1) Supply both charging and leakage current in the high-tension cables
(2) Provide the leakage current in the spark-plugs
(3) Fire a relatively lean or a relatively rich mixture
(4) Produce heat enough at the spark-gap to insure rapid flame propagation
(5) Permit accurate timing and
(6) Allow, in general, a high puncture value for the secondary wave, followed immediately by a discharge of energy sufficient to perform the requirements previously mentioned

Keeping these fundamentals, engine and ignition requirements in mind, let us consider some of the characteristics of the two systems. To break down a given dielectric or insulating medium by disruptive discharges, not

[1] M. S. A. E.—Patent attorney and consulting engineer, Splitdorf Electrical Co., Newark, N. J.
[2] See THE JOURNAL, November, 1919, p. 364.
[3] See *Automotive Industries*, Nov. 28, 1918, p. 907.

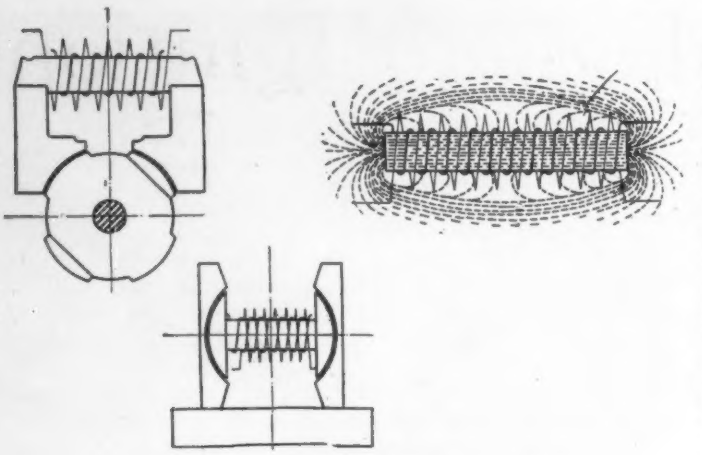


FIG. 1—LONG CORE MAGNETIC CIRCUIT

only must the gap voltage be sufficiently high, but also a certain minimum amount of energy must be available for the reasons already stated. The gap or secondary voltage is of course raised by increasing the number of secondary turns; the available energy, however, is not increased by the secondary turns but depends upon the primary volt-amperes, or the energy stored in the magnetic field. Increasing the secondary turns beyond a certain limit is therefore of no avail, as the spark will fail to pass in all cases whenever the available energy in the primary winding falls below a certain minimum.

In the battery system, there is a relatively long core with an open magnetic circuit, as shown in Fig. 1. From the very nature of its construction, a considerable amount of the primary flux never embraces all of the secondary turns. The opinion may be advanced by the battery-ignition advocate that his is an easier coil to wind and insulate. This may be true when his coil is compared with some styles of magneto winding, but it does not apply to the type of construction shown at the left of the battery coil in Fig. 1. Furthermore, since the efficiency of the combination of a Siemens type of magneto is greater than in the battery system, not so much wire is required on the armature and this can be insulated without great difficulty. In any of the devices ordinary care must be exercised.

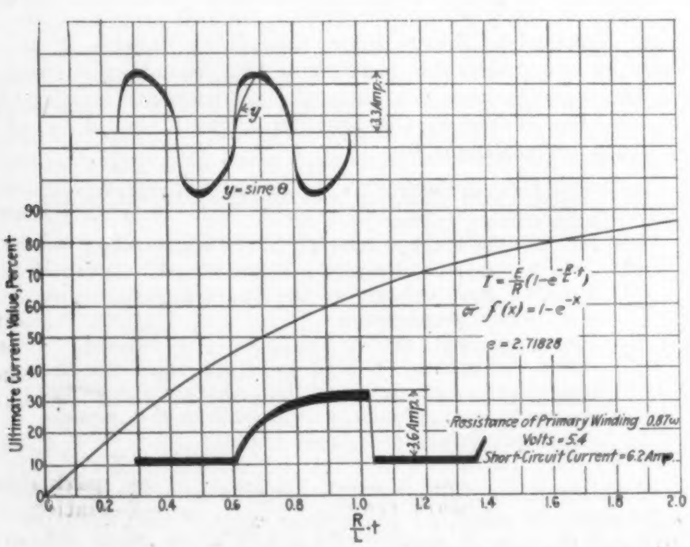


FIG. 2—TIME FOR BUILDING UP THE PRIMARY CURRENT AND FORMULA FOR DETERMINING ITS VALUE

When the circuit-breaker closes, in the battery system, the current must rush in through the primary winding against the counter electromotive force set up by the self-inductance. The theoretical time for the building up of the primary current is indicated by the curve and formula shown in Fig. 2. This formula will be recognized as that developed by Helmholtz. Put into words, it means that, after a lapse of t seconds, the self-induction in a circuit on making contact has the effect of diminishing the strength of the current by a quantity, the logarithm of whose reciprocal is inversely proportional to the inductance, and directly proportional to the resistance of the circuit and to the time that has elapsed since making the circuit. The quantity L/R is the time constant. It is the time required by the current to rise to a definite fraction of a value, namely, $\frac{e-1}{e}$ or 0.634. Below this curve is a copy of an oscillograph record of the action of a well-known two-spark battery-ignition system. It will be seen that it has many of the characteristics of the theoretical curve. These curves indicate at once that inductance has a marked effect upon a battery system, tending to retard its action. The lower curve also shows the magnetic inertia inherent in this type of system, for, in such a system, when the current is increasing in strength, inductance causes it to increase more slowly and when current is dying out inductance tends to prolong the current. This will also be noticed in the oscillograph record from which this curve was taken.

In the magneto the magnetic circuit is very nearly closed, only two very short air-gaps being introduced. The coil core is short and the leakage between the primary and secondary turns is reduced to a low minimum. Fig. 1 shows a magneto of the Siemens type and one of the inductor type, although the magnets are not shown. The rate of change of the primary current building up is greatly in excess of that of the battery system, because of the mechanical reversal of the flux through the core, due to the turning of the rotating element. In the upper part of Fig. 2 is shown a copy of an oscillograph record of the short-circuit current of a magneto; to indicate the rate of change, a half cycle of a true sine wave having the same maximum value is plotted.

In the battery system, the flux must die out, but in the magneto it is driven out. This operation may be likened to a water pipe where, in the battery system the pipe has to be filled at one end, then the filling force removed and the water allowed to run out of itself, while in the magneto a similar force is applied to the pipe at the opposite end and the old water forced out with no loss of time. It is this loss of time or electrical lag in the coil of the battery system, which varies considerably in different battery systems, that makes this type of ignition less accurate than the magneto in its timing and firing ability. The breaker can be set accurately enough, but the magnetic inertia unbalances the condition. As the speed of the engine increases, the time of contact allowed for the coil to build up is decreased and the amount of energy stored in the primary winding is reduced, with a consequent falling off of the energy in the secondary spark, shown in subsequent figures. Various attempts have been made to overcome this difficulty by introducing devices to increase the interval of time that the circuit-breaker is closed at the higher speeds, so as to allow the primary voltage of the coil to build up. This must be compensated for on an engine by a greater spark-advance, and it appears that no better proof is

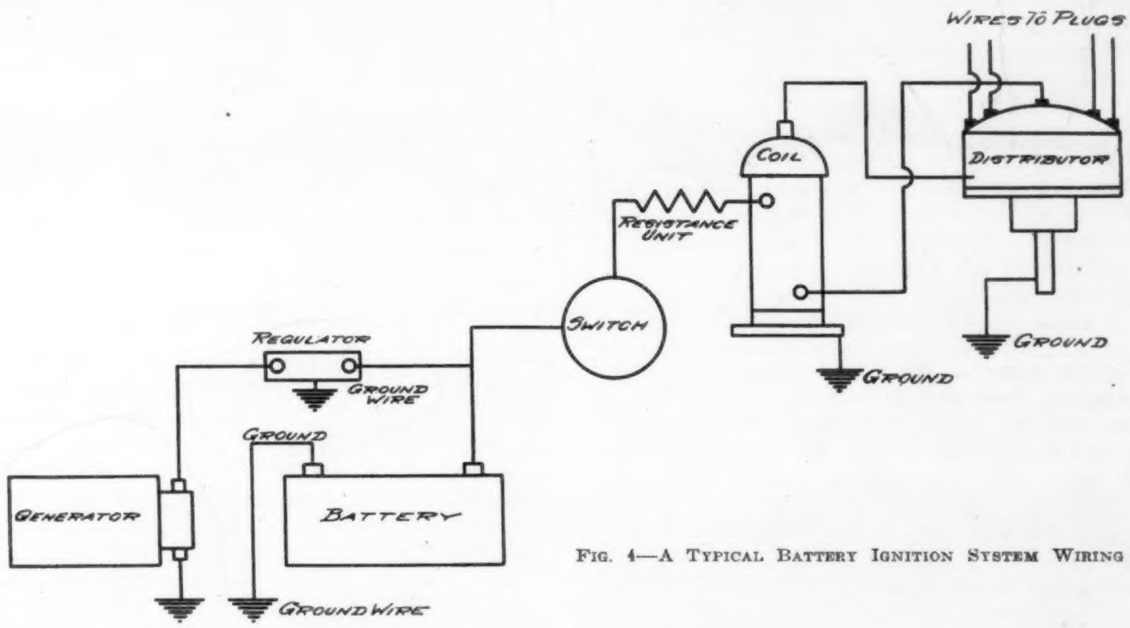


FIG. 4—A TYPICAL BATTERY IGNITION SYSTEM WIRING DIAGRAM

required on this point than the admission by the battery-ignition advocates that they require greater spark-advance at high altitudes, where the carbureter mixture has become changed so that the "initial impulse" no longer functions as before.

In the battery-ignition systems in commercial use at present, the spark coils are of necessity very much of a compromise in design; that is, a battery coil designed to give sufficient heat energy at high speeds of the engine with which it is used, will draw an abnormal amount of primary current at low speeds, with consequent destruction of the breaker-points and a drain on the battery, and vice versa. A coil designed to draw a permissible amount of current at low speed will lose a large amount of its secondary heat energy at high speed.

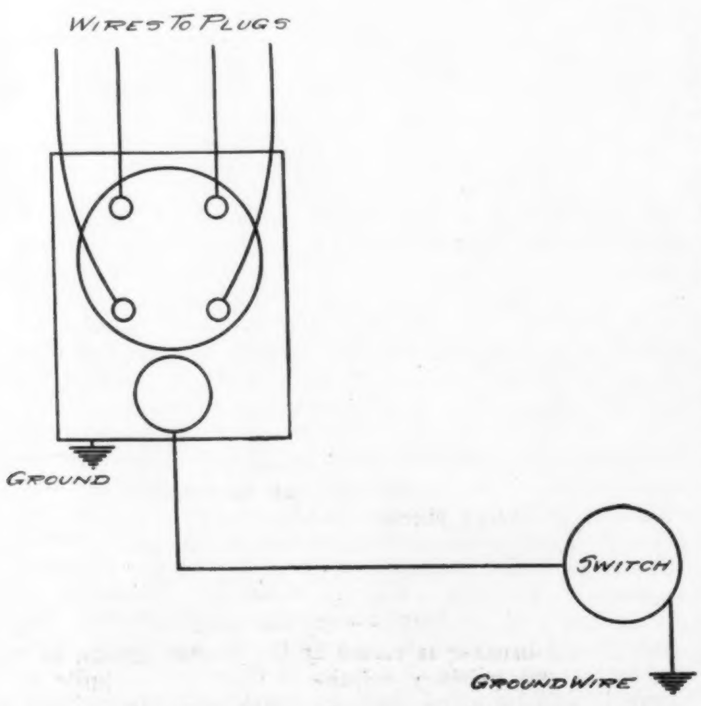


FIG. 3—A TYPICAL MAGNETO WIRING DIAGRAM

This is indicated in the figures which follow, the simplicity of wiring of the magneto-system being noted in Figs. 3 and 4. In a well-known battery system for two-spark ignition, the current drawn from the battery is approximately 7 amp., which is more than the entire lighting and horn load on the average automobile. This is indicated by the lower curve of Fig. 2. It is to be understood, of course, that the average current drawn is less than 7 amp., but the amount is such that I should consider it prohibitive for a light automobile, because to care for such a system the battery would need to be increased and likewise the generator. This would involve an increased cost of each of these units as well as a material increase in the amount of weight to be carried.

COMPARATIVE SPARK VALUES

Let us now consider a very prominent feature of the high-tension magneto, which gives it another and decisive advantage over the battery system. This feature is the rotation voltage produced by the secondary coincidently with the arcing of the spark at the spark gap. This rotation voltage produces an arc flame in the magneto spark, which I contend is necessary to produce rapid flame propagation, burn a lean or a rich mixture, provide the energy necessary to charge the high-tension cables and care for leakage in the cables and in the spark-plugs themselves. As measured in electrical units, the power supplied by this rotative action is a fairly large percentage of the total energy delivered by the secondary and in some cases the spark is hot enough so that the molecules of the wet mixture can be actually vaporized and then ignited, a condition not inconsistent with that existing during the period of starting. A picture of the magneto and battery sparks is given in Fig. 5, wherein it is seen that the magneto spark is composed of two parts, and the initial discharge is accompanied by the arc flame known in the art as "whiskers." When considering the magneto curves shown, it should be remembered that these "whiskers" are instantaneously expanding into the gaseous mixture immediately the spark arcs the gap. It appears reasonable that the association of these two component parts of the magneto spark, engaging as they necessarily must more molecules of the mix-

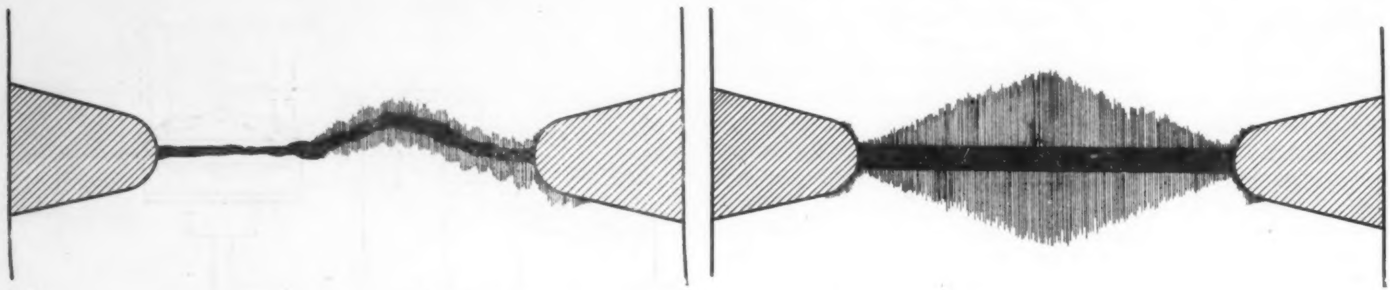


FIG. 5—TYPICAL BATTERY (LEFT) AND MAGNETO (RIGHT) IGNITION SPARKS

ture, will ignite more of them and cause more rapid flame propagation than the battery spark, which it is admitted has only the initial discharge, and this is relatively thin and of low heat value. It is a curious coincidence that those who offer nothing but an initial discharge are the ones who say that it does not require much heat energy in the spark to ignite the fuel mixture in an engine. Stating that the reserve power inherent in the high-tension magneto is not required, is merely camouflaging the issue.

Fig. 6 shows the heat values per spark of three different magnetos, in comparison with the heat per spark of the battery-ignition system used on the Liberty engine. These curves are taken from the Bureau of Standards reports and check closely with observations made by others. An effect on the heat of the spark can be produced also by the insertion of a small gap in the distributor circuit and by an improperly constructed cam; in particular, the functioning of the magneto can be controlled by the cam. In connection with Fig. 6 it is to be remembered that the battery-ignition system shown was a special 8-volt installation. A comparison of the same Liberty engine equipped with battery and with magneto ignition is illustrated in Fig. 7, wherein it is seen that the engine operated at a lower temperature with less consumption of both gas and oil, with an increased number of revolutions per minute. It is to be noted also that the battery advance was 8.5 deg. more than on the magneto with spark-plug gap of only 0.012 in. as against 0.020 in. when the magneto was operated. It is generally true, I believe, that with battery-ignition systems the spark-plugs must be run with smaller gaps, which prohibits the spark from coming into contact with a sufficient number of molecules of the mixture to produce rapid flame propagation. The gaps can be set so closely that the spark will pass without igniting the charge. Characteristics of the two types of ignition are illustrated in Fig. 8, which is a reproduction of records taken at three different speeds. The current output at the highest speed from the magneto is substantially

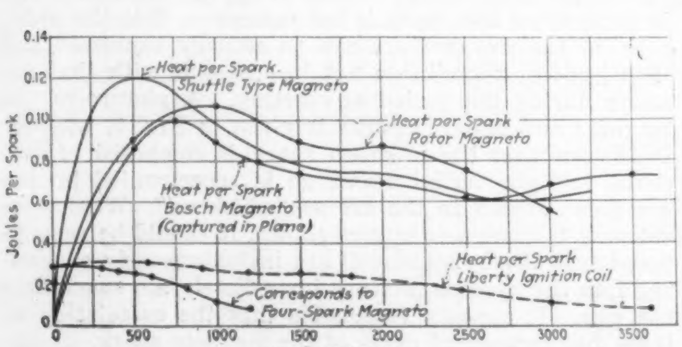


FIG. 6—HEAT VALUES OF SPARKS FROM THREE DIFFERENT MAGNETOS

double that of the battery system, while at the lower speeds the battery system has but little more than one-half the current output of the magneto. It will be noted also that the duration of the magneto spark is about three times that of the battery spark, and that there is some variation in the battery sparks at all three speeds.

It was considered impossible to build a magneto that would fire the Liberty twelve-cylinder engine, on account of the angularity of the cylinders. Some of the difficulty is depicted in the magneto curves; yet the problem was not insurmountable and even the weaker sparks from the magneto are much greater than in the battery system

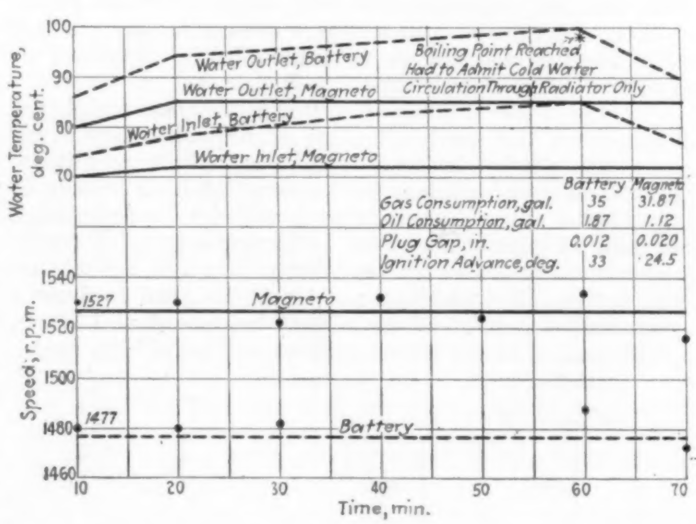


FIG. 7—COMPARATIVE CURVES OF THE BATTERY AND MAGNETO-IGNITION SYSTEMS OF THE LIBERTY ENGINE

and the total result previously illustrated in Fig. 7. Reference has been made to a two-spark battery ignition system. Fig. 9 shows, in the upper portion, two curves of this battery system taken at two different speeds. From the top curve was taken a section shown in Fig. 2 from which, as well as from the one taken at the speed of 1335 r.p.m. it will be seen that there is a loss of time in the current falling to zero at the instant of break. Below these two curves is illustrated the more rapid change in the magneto. It will be noted that the two lower curves were produced with the use of an impulse coupling, which will be referred to later. Fig. 10 in the upper portion shows the secondary battery sparks at 170 r.p.m., while the curves below show the magneto at 125 r.p.m., using an impulse coupling. Fig. 11 shows the character of the battery and the magneto sparks operating under the same conditions; also the secondary spark is shown with the battery operating at a speed of 90 r.p.m. From this curve it will be noted that the sparks are considerably out of synchronism, so much so that probably one is en-

tirely wasted. Fig. 12 illustrates the secondary sparks from the battery and the magneto under the same condition of operation and also the battery system operating at an intermediate speed. Fig. 13 illustrates secondary sparks from the battery and the magneto, operating under the same conditions, as well as the battery spark operating at a speed below that shown in the top set of curves. Attention is called to the thinning out of the battery spark, as well as to its irregularity at the highest speed, its maximum value dropping off, while the maximum value from the magneto increases.

Storage Batteries and Auxiliary Devices

The curves just mentioned were taken with a fully-charged battery at a battery temperature of 80 deg., and are descriptive of a two-spark battery system which draws a relatively large amount of current from the storage battery. As to what happens on a cold morning, even with this special battery ignition system, it must be remembered that the capacity of a lead storage battery falls off with decrease in temperature as indicated by Fig. 14, which was taken from a battery manufacturer's data sheet, showing that at a temperature of 4 deg. above zero the battery has only 50 per cent. of its normal rated capacity. The freezing point of storage-battery electrolyte is given in the bottom curve, from which it is seen that if the batteries are kept in approximately a fully-charged condition, usual temperatures will not freeze them. Generally speaking, under this condition, when the starter switch is closed, the battery voltage drops to 4 or even less and there is a marked falling off in the spark energy. This is shown in Fig. 15, where, with a battery voltage of 4½, the secondary spark has dropped about 25 per cent in value; while with a battery voltage of 3½, one

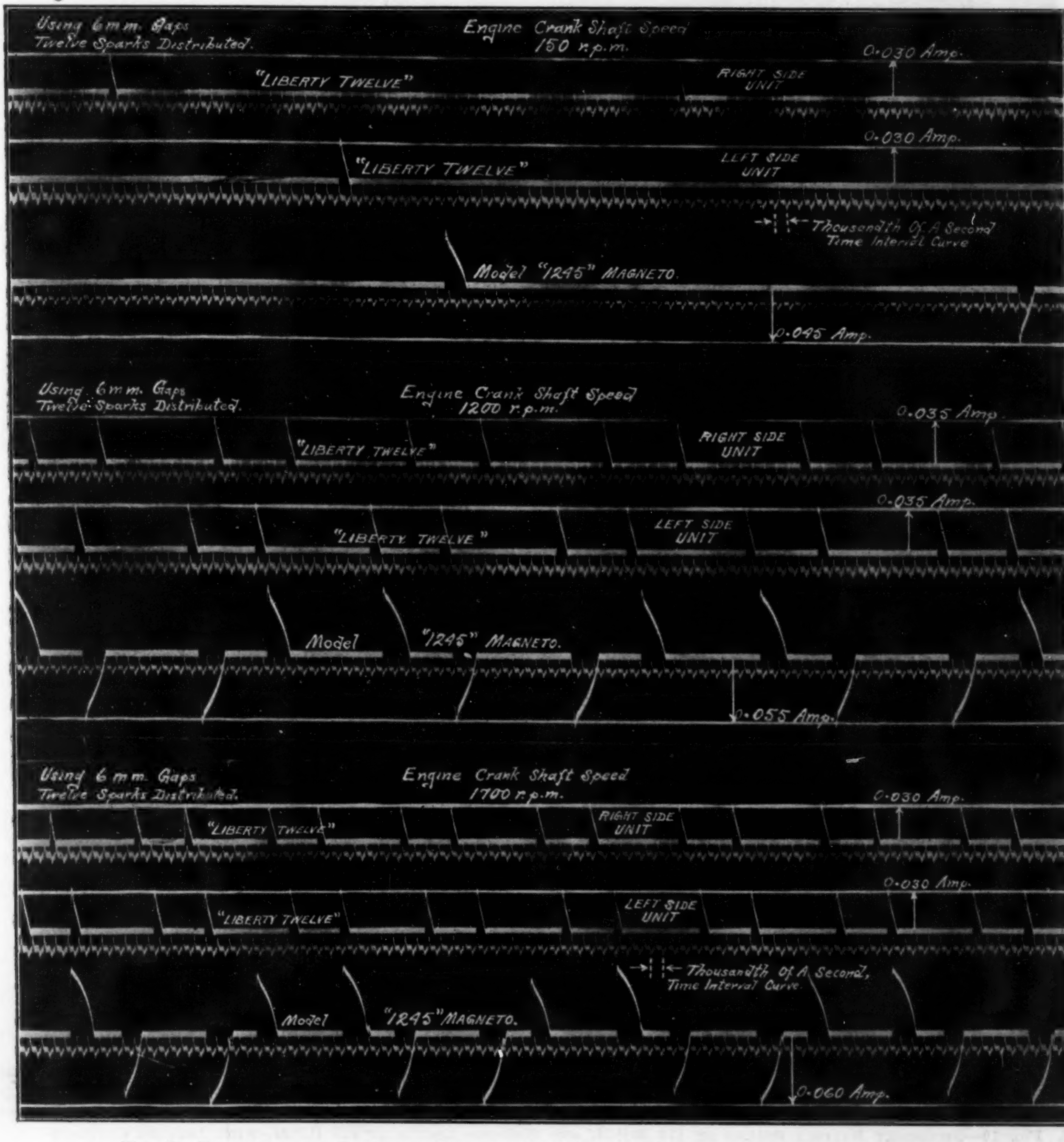


Fig. 8.—Characteristic Curves of Battery and Magneto Ignition at Three Different Speeds

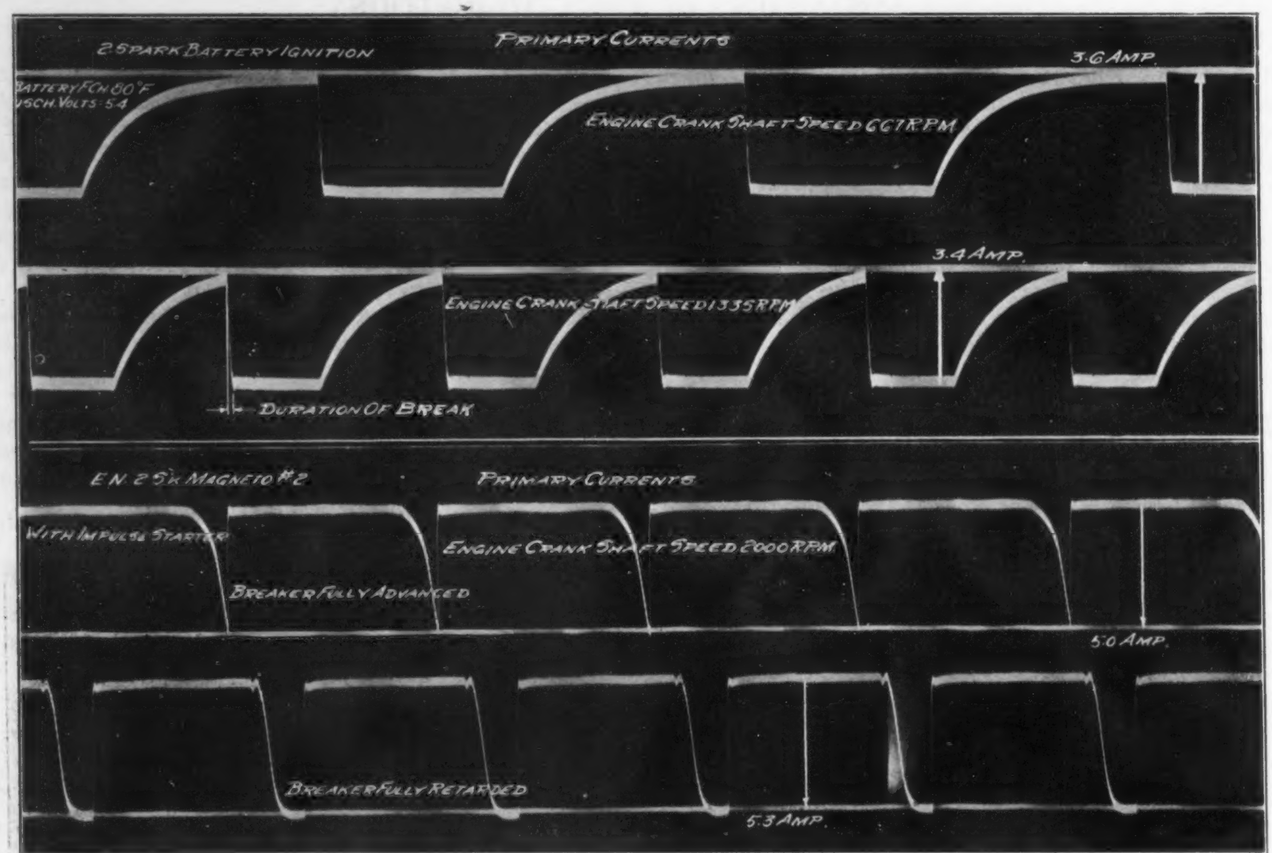


FIG. 9—CURVES OF THE TWO-SPARK BATTERY SYSTEM AT DIFFERENT SPEEDS

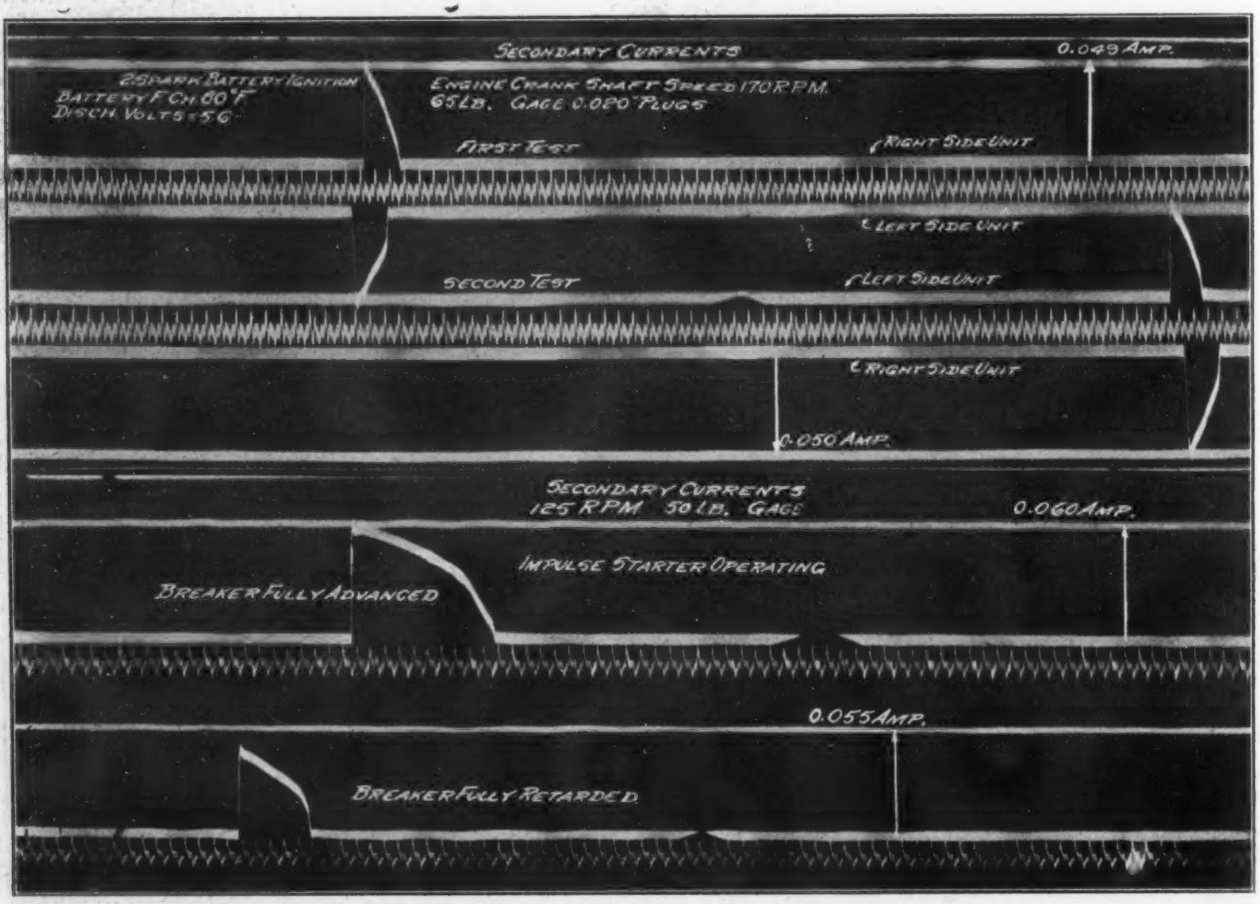


FIG. 10—SECONDARY BATTERY SPARKS AT 170 R.P.M. AND MAGNETO SPARKS AT 125 R.P.M. WITH IMPULSE COUPLING

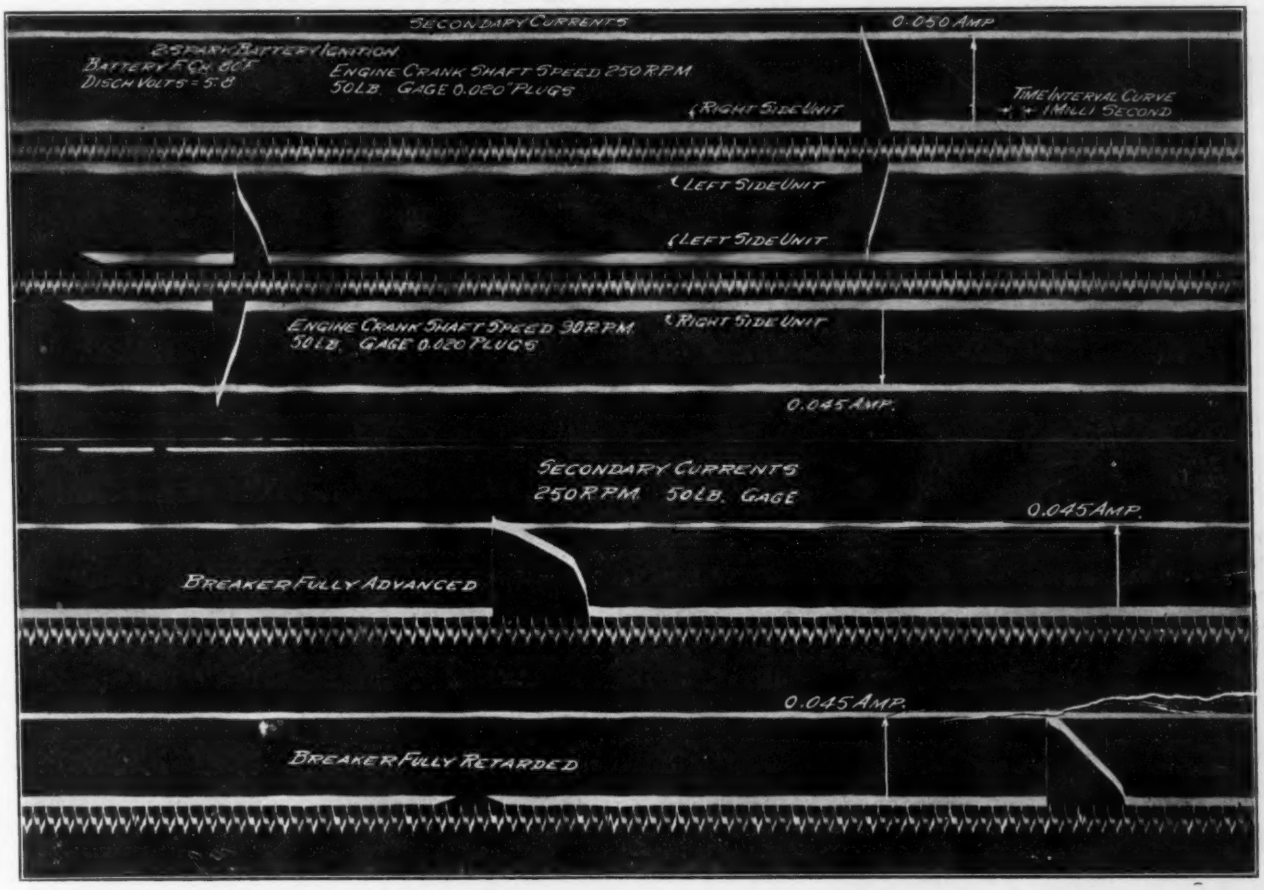


FIG. 11—MAGNETO AND BATTERY SPARKS UNDER SAME CONDITIONS AS FIG. 10; ALSO SECONDARY BATTERY SPARKS AT 90 R.P.M.

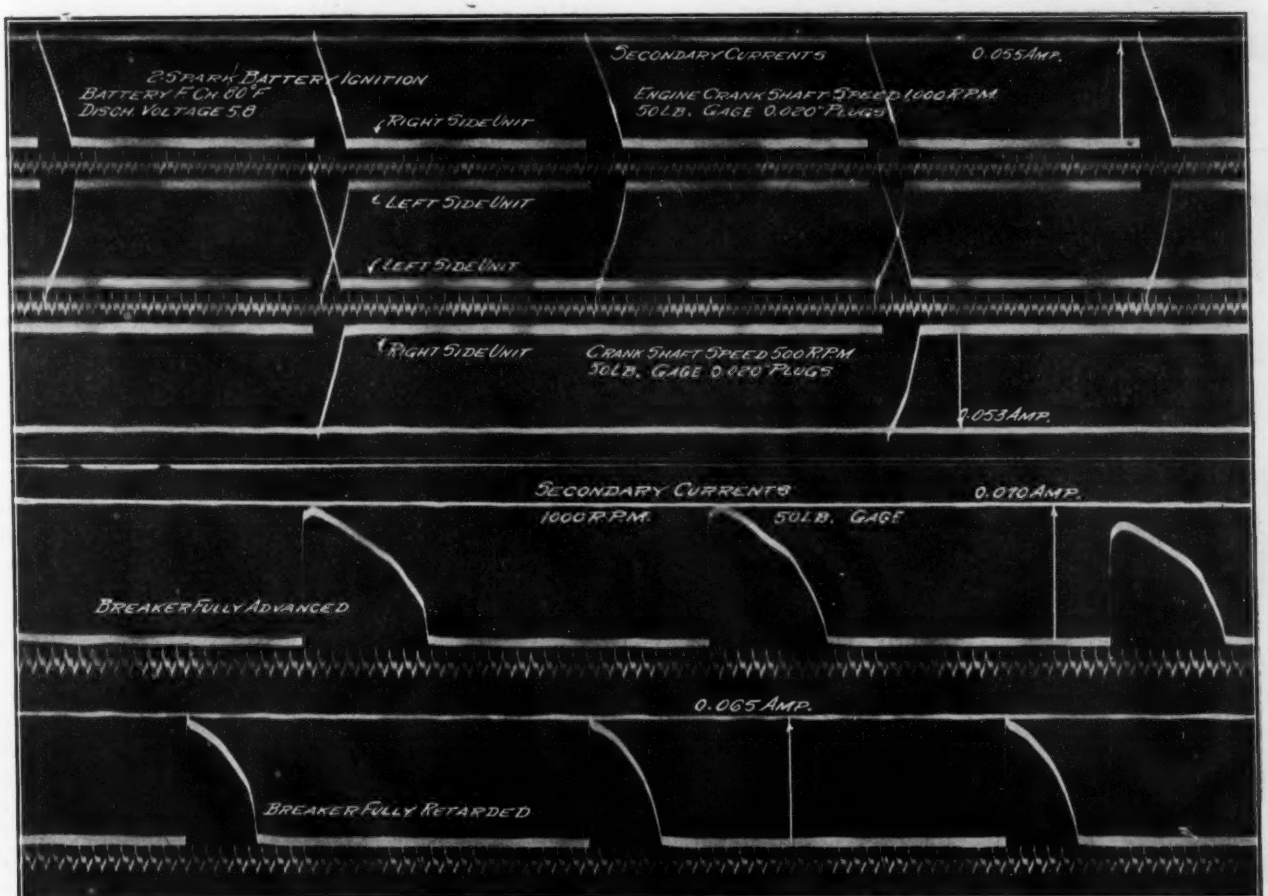


FIG. 12—MAGNETO AND BATTERY SPARKS AS IN FIG. 10; ALSO WITH BATTERY AT AN INTERMEDIATE SPEED

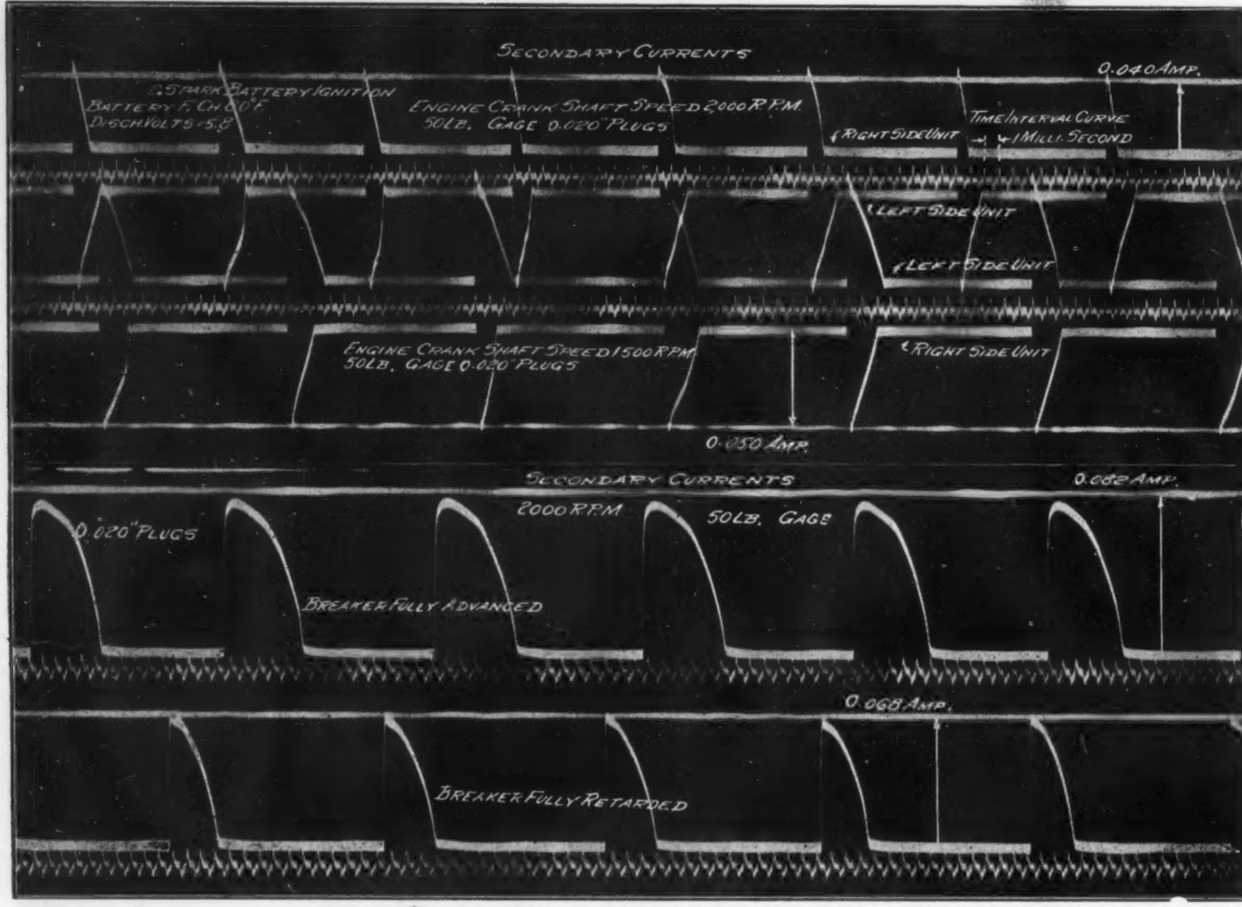


Fig. 13—Magneto and Battery Sparks Under Same Conditions as Fig. 10; Sparks with Battery System Operating at a Lower Speed

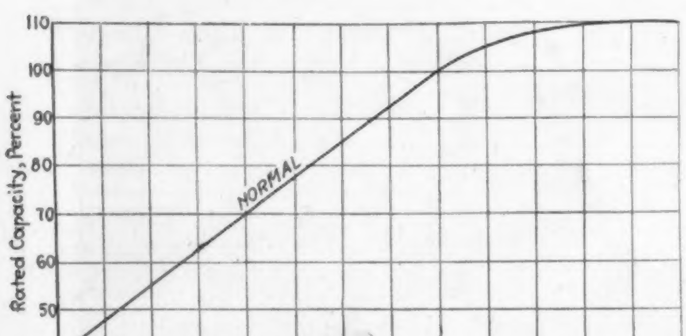


Fig. 14—Decrease in Storage-Battery Capacity Resulting from Exposure to Low Temperatures

spark has dropped out entirely and the other is very weak. The third set of curves taken at 50 r.p.m., with discharge voltage at 3.8, shows irregular sparks both in value and timing; at 3.5 volts these differences are more pronounced.

In the battery system too much depends upon the weakest member. A storage battery is abused probably more than any other part of the electrical equipment on an automobile. To the average car owner it is only a box and is supposed to function whether it is charged or not. Its action is electrochemical and, from our present knowledge of secondary batteries, its life is relatively short. It has no moving parts and the car owner does not suspect trouble, particularly when no ammeter is provided.

The battery on a magneto-equipped car may become inoperative, but the owner can start and operate his car and possibly restore the battery himself, without consulting an expert. If dependent upon the battery for ignition, it must be restored by an expert if it becomes inoperative.

Many battery-ignition systems are provided, at an additional expense, with means for preventing the battery from running down should the ignition switch be left in the closed position and the timer stops on a contact, which frequently occurs. One device introduces a resistance in the primary circuit, which merely prevents the battery from discharging fast enough to burn out the coil. Another is a thermostat to control the primary circuit and open it after a given interval of time. But these and other means do not always prevent the exhaustion of a

battery. I recently had an experience of this nature. A youngster amused himself in my machine by pushing the battery button. I found, a week thereafter, that the safety device had failed to prevent the total discharge of the battery. All that was necessary was to use the hand-crank and start on the magneto; after a short run the battery was in commission again.

Impulse Coupling

In reference to impulse couplings, these devices are advantageous in starting large truck and tractor engines, which use magnetos practically altogether. While operating conditions on tractors are extremely severe, the percentage of magneto trouble has been very low. The impulse coupling acts automatically to get a spark equivalent to that of a rotative speed of the magneto of 600 to 800 r.p.m., no matter how slowly the engine is turned over the high point of compression. This device is illustrated in Fig. 16. It consists of a driven member fastened to the magneto shaft and a driving member operated by the engine. The members are operatively connected by a spring *a*, brought into action for giving an impulse to the driving member through a pawl *b* which engages the notch *c* in the driven member, thereby preventing it from rotating until the cam *d* on the driving member passes beneath the nose of the pawl, lifting it out of the notch *c*, at which time the spring *a* drives the driven member and rotating part of the magneto rapidly forward, producing a hot spark. The pawl *b* is automatically brought into engagement at a certain predetermined low speed by the detent *e*, having a nose *f* engaging the projection *g* on the pawl. As soon as the speed is approximately 200

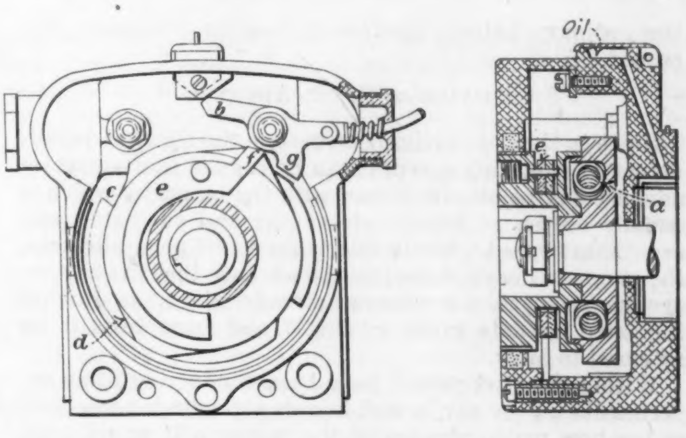


Fig. 16—Typical Form of Impulse Coupling for Magnetos

r.p.m., the detent *e* automatically takes a position such that the nose *f* will not engage the pawl again until the speed has dropped to about this value. The character of the sparks is shown in the lower part of Fig. 10.

The impulse coupling is particularly adapted to use in connection with trucks and tractors. It can be used on passenger cars also, although here the need is not felt for the reason that a good high-tension magneto will deliver good sparks at speeds considerably below the rotatable speed of an internal-combustion engine. Furthermore, the present-day starters under ordinary conditions are capable of cranking an engine at speeds such that the magneto will actually start the engine more easily than

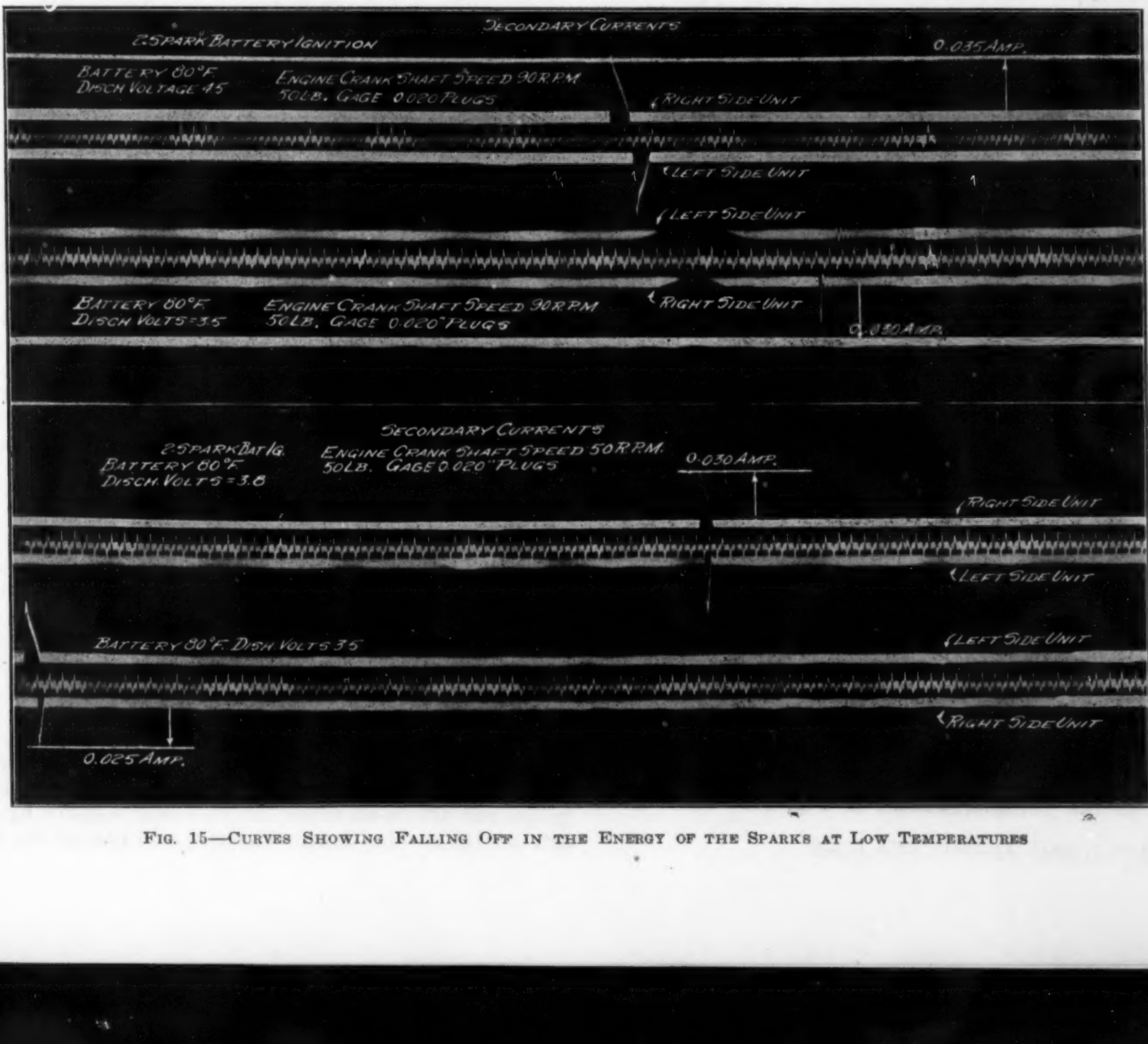


Fig. 15—Curves Showing Falling Off in the Energy of the Sparks at Low Temperatures

the ordinary battery-ignition system as previously discussed.

Degree of Spark-Advance

Since in the battery-ignition system the timer is usually driven at camshaft speed, it can be argued that a greater advance can be obtained than with the magneto, which is usually driven at crankshaft or one and one-half times crankshaft speed. While this is no doubt generally true, the magneto does not require the advance that the battery system requires, for reasons already given, as further indicated by data given in Fig. 7 and from tests to be referred to later.

Within the past year I have been conducting some experiments on my car, a well-known six-cylinder machine, to see how much advance of the magneto it would take. In these tests I have used an automatic advance capable of 68 deg. on the magneto or 45 deg. on the crankshaft. Tests were made before cleaning out any carbon in the engine and immediately after, and it was found that the engine would not take anywhere near this amount of advance. At present I have an automatic advance under test, having approximately a 40-deg. advance on the magneto or 26 2/3 deg. on the crankshaft. While the tests have not yet been completed, I am of the opinion that this engine will not take all of this advance. The type of governor used is shown in Fig. 17 and is constructed so that the device can be adapted readily to the performance curve of any engine. For example, in the first tests on this governor the second spring was entirely too weak and the advance was too great at the speed which brought the second spring into operation. A slightly heavier spring corrected this and preliminary tests show up wonderfully well. Final results are about to be determined.

Attention is called to the construction of the device shown in Fig. 17, wherein the pivot points of the moving members are all in the same straight line. This construction is such that at low speeds the weighted arms are substantially locked, so that there is no lost motion or jumping which would interfere with the correct operation of the magneto; yet the weighted arms are in a position to respond readily to the centrifugal force to advance the magneto in proper time without jerks. Attention is called to the simplicity of construction of this governor. The drawing in the upper left corner shows one section of the parts in the normal and very low-speed running positions, while the drawing in the upper right corner is the same with the parts in the high-speed position. From these two views it will be noticed that the weighted arms act on the sleeve *f* which is fastened to by springs *c*, *d* and *e*, which are brought into operation successively in proportion to the speed, and that the weighted arms act on the sleeve *f* which is fastened to the magneto shaft *g* in a suitable manner, as by a nut *h*. The outer end of the sleeve *f* has a seat for a collar *i*, which forms the inner end of a coupling member *j* and a second pair of weighted arms corresponding to *a* and *b* is carried on studs fastened to the casing member *k*, which studs also support the weighted arms *a* and *b*. These latter arms serve, as stated, to rotate the sleeve *f* and shaft *g*, while the other set of arms rotate the entire casing with respect to the sleeve *f*. Therefore, if the sleeve *f* is advanced 20 deg. by one set of arms, the casing is advanced an equal amount by the other set of arms, so that the total advance is 40 deg. on the magneto. An auxiliary spring is used to modify the slow-speed action of the governor, shown in Fig. 17. These governors are of a very compact construction, with the operating parts completely enclosed, and are of such a radius as to be within the mounting center of the magneto-shaft, namely 1.771 in. Furthermore, the design is such that a range of advance can be obtained, if necessary, considerably beyond the requirements of any engine with which I am familiar. This method of advance is such that the rotating element of the magneto always breaks at the point of maximum efficiency.

Flame Propagation

Reverting to the question of flame propagation, in a paper by Donald MacKenzie and R. K. Honoman on the Velocity of Flame Propagation in Engine Cylinders,[4] the results given indicate a speed from 21 to 41 ft. per sec., which is low compared with the velocity of the air inflow, but the average speed is close to the piston speed used. A. P. Young, a well-known British engineer, states that pressure diagrams taken of engines show that a time interval of about 0.0035 sec. elapses before the pressure reaches its final value and that the pressure rise certainly depends on the rate of flame propagation. It appears to me that flame propagation is aided and promoted by a spark having hot whiskers on it, and if we consider again Fig. 13 the arc flame carrying whiskers which endures for at least 0.001 sec. in the case of the magneto must be extremely useful in burning the mixture. In the battery system the secondary spark is all initial; it is completed in less than one-third the time taken for the pressure to rise to its maximum value, and within the time at which the magneto current stays at a point close to its maximum or initial value. No better proof of this is needed than the operation of a magneto on a truck, the magneto having a characteristic curve similar to the upper curve in Fig. 13, or one in which the curve is substantially limited to an initial impulse with no follow-up current. There is an extraordinary difference between the operation of a truck with a magneto of this initial-impulse type and with one having characteristics such as are shown in the lower set of curves in Fig. 10.

If further proof is necessary, the results of a test made by a well-known engineer on a well-known car are given in Table 1. The start was at the foot of a hill, reaching a speed of 10 m.p.h. at a given point and ending at the top of the hill at a given point. The throttle was wide-open at the starting point and the time was taken by a stop-watch.

From this test we note that with two-spark ignition the magneto with only a 15-deg. advance was faster by 4 m.p.h. than the battery with over a 24-deg. advance, assuming some of the automatic was in; that with a 7½-deg. advance on the magneto and a 12-deg. or greater advance on the battery, depending upon the position of the automatic advance, the car was 8 m.p.h. faster; and that in the full-retard position the car was 25 m.p.h. faster with the magneto. The fact that the driver has a lever which he can operate in either case indicates that, with the battery ignition, he is very likely to be driving much of the time at a point where the engine will be using much fuel with loss of power and collecting carbon.

The comparison between the magneto and single-spark battery ignition is even more striking. However, two things stand out prominently; the superiority of magneto over battery ignition, and the increase in power and efficiency by the rapid flame propagation provided by the two sparks. Furthermore, we have here another demonstration of the superiority of a single spark having sharp initial and follow-up characteristics over a spark having only an initial discharge. The magneto has all the bat-

[4]See The Journal, February, 1920, p. 119.

[8]TABLE 1

	Two-spark Ignition		Single-spark Ignition	
	Speed at Hilltop m. p. h.	Time in sec.	Speed at Hilltop m. p. h.	Time in sec.
Magneto, full manual advance	34	48.5	31	52.5
Battery, full manual advance plus automatic	30	56.2	22	80.0
Magneto, one-half manual advance	35	46.2	29	50.5
Battery, one-half manual advance plus automatic	27	57.5	10	100.0
Magneto, full retardation	32	49.2	25	52.5
Battery, full retardation plus automatic	7	138.0	Dead	Dead

[8]Timing, magneto and battery, top D-C full retard. Advance to crankshaft, magneto 15 deg.; battery, manual, 24 deg.; battery, automatic, 14 deg.

tery-spark characteristics, but in a higher degree. It has also a reserve that backs up and carries out what the first operation starts. The magneto finishes what it starts. The battery starts something it does not finish.

As a further indication of the superior sparking qualities of magneto over battery ignition, the fastest time ever made by an automobile, in excess of 149 m.p.h., was made by a magneto-equipped car; the fastest motor boat was equipped with a magneto; likewise the fastest motorcycle, in the 1-mile and other speed records; first, second and third places in the last 500-mile race at Indianapolis were taken by magneto-equipped cars; practically all fire apparatus and substantially all airplanes used in the war were equipped with magnetos, as well as the R-34 dirigible, in the first non-stop flight across the Atlantic, and the aircraft used in the England-to-Australia flight. In connection with the airplane, altitudes and temperatures within human endurance do not affect the magneto.

While producing all of the results required of an ignition system, which results have been set forth, further advantages of magneto over battery ignition can be briefly summarized as follows:

(1) It does not depend upon a battery and a generator for starting and running, the human element of forgetfulness does not affect it and there are fewer parts to get out of order, in comparison with the generator, battery-coil system

(2) Safer starting is assured

(3) It gives more power with less oil and fuel, cooler and smoother-running engines and cleaner spark-plugs

(4) It does not deteriorate rapidly with age, is more compact, is not tied up with a battery and a generator, has only one wire to the magneto and simply a grounding switch, as is indicated by comparisons shown in Figs. 3 and 4

The Discussion

C. E. Wilson:—From my point of view, if magneto and battery-ignition systems are properly designed and have a hot spark, either is satisfactory. Mr. Libby speaks of the relative efficiencies of the magnetic circuit. That is really a question of design. A number of both systems are being distributed and a number of coils are made with very much more nearly closed magnetic circuits. In a way he has compared a favorable magneto design with what I consider a rather poorly-designed battery-ignition coil. These undesirable points can be remedied. It is simply a question of what amount of iron and copper the manufacturer is willing to put into the equipment.

Mr. Libby has emphasized the degree of heat of the spark, engine knocking, etc. In my experience in driving, an engine is more likely to knock when hot than cold; also, when the energy developed by the gas explosion in an ordinary engine is calculated, this rate of energy production is somewhere between 5 and 10 joules. We are trying to help burn the gas with a spark which we measure in milli-joules. The point I wish to emphasize is that, in the first very small fraction of a second after the gas has started to ignite, the heat produced by the burning of the gas outshadows the effect of the spark. In a two-spark battery system where the two cams were not in synchronism, Mr. Libby stated that one could be left out of synchronism. This really means that the whiskers of the magneto spark really do no good.

Regarding spark advance, with the modern battery-ignition system there is no time lag in the production of the spark itself, and the difference in the advance required for a given engine is, really a very small amount; it practically disappears, and there should be the same advance for both battery and magneto ignition. I do not know all the details that entered into the test mentioned but from the results it appears that the battery-ignition system had too much advance; the curves of the Liberty engine looked that way in particular, as if too much advance on the battery system produced heating of the engine, trouble with the temperature of the water in the radiator and loss of power.

The question of cam design determining the time of contact is to some extent the same in both ignition systems. The reason for a long period of contact is to get the spark on the battery ignition at high speed. The time of contact for the battery system is a definite period, and is required to pull the current up to a certain value to produce the desired spark. A magneto may be designed with too short a cam and thus too short a time of contact is obtained.

Victor Greiff:—Regardless of the influence of spark heat upon the engine performance, the fact remains that we wish to obtain a certain amount of energy in a spark. I will not analyze where the energy is going or what it will do, but energy produces the spark and with no energy we get no spark. There are many other places

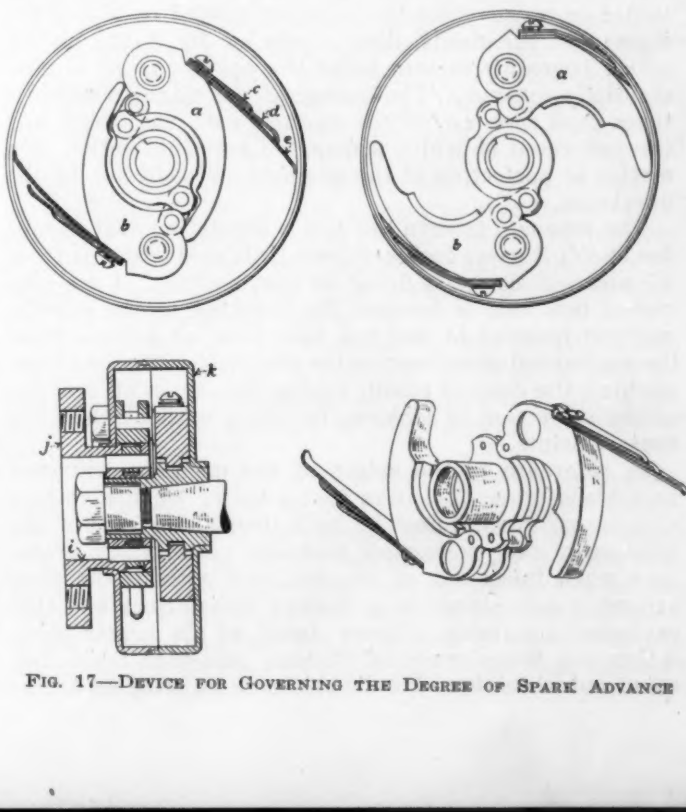


Fig. 17—Device for Governing the Degree of Spark Advance

the energy can go or, as Mr. Libby indicated, many losses which must be supplied before the spark can be produced. The energy in this case is to be turned into a spark. If the energy available is not sufficient to supply all of these losses there will be no spark.

Let us analyze the ignition system. Four elements are included (*a*) a source of energy; (*b*) means of storing up that energy; (*c*) an interrupter which causes liberation of that energy; and (*d*) a transformer to step that energy up to high potential for sparking.

In the battery system we have a source of energy that is like a stream of water, not constant but contracting with an increase of speed; for, in a battery system, as indicated by the ammeter, the current decreases as the speed increases, or the stream of power is becoming smaller as the number of sparks we must produce is increasing. This stream of energy is being chopped off into the required number of sparks. As the stream contracts and the number of sparks increases, a point is reached where there is little to operate with. We have been told that some of the best battery systems have poorly designed coils. It must be remembered that this stream of energy will not build up a coil with a large inductance, will not build up through the inductance of a magneto armature and will not charge it at a sufficiently high rate to give sparks at high speeds. That is how the source is compared in the two cases.

Having produced the energy, how shall it be stored? That is a matter of inductance. It is to be stored as electro-kinetic energy. Referring to the well-known hammer analogy, let us consider the pile-driver of the ordinary type. The hammer is hoisted and dropped. If the number of blows is increased five times, the hammer can be lifted only about one-fifth as far, and the energy in each blow is less. The steam pile-driver puts power behind each blow no matter how often the blows are delivered. Another analogy is that of striking a nail with a hammer to get energy. If we try to speed up this action, we will find that beyond a certain rate one's arm will not accelerate the hammer fast enough and the blows will weaken. As the speed increases, the magneto generates energy proportionate to the number of sparks required; for that reason the spark energy is maintained as we see from the carefully plotted results of the Bureau of Standards' tests shown by Mr. Libby and in which beyond a certain point the spark energy is substantially constant. The energy of the magneto spark is there at all speeds after the magneto gets into action, and the low speed at which a magneto gets into action is a matter of perfection of the magneto and selection by the purchaser.

The magneto interrupter has a reputation that speaks for itself; it gives comparatively little contact-point trouble and will not miss firing on that account. I am convinced that this is because the breaking of the current and the reversal of the flux take place at a time when the mechanical power assists the electrical action in accomplishing the desired result, taking the strain off and enabling the action to continue for years without filing the contact points.

In reference to the action of the magneto armature as a transformer, I believe that a better small high-tension transformer cannot be built than in the case of the winding of the present-day magneto. A magneto armature when taken out of its shell and without the steel around it acts simply as a leakage transformer and still performs admirably. Every detail of its construction makes it a transformer of efficiency and high insulating value and while there are difficulties in building an armature, the finished product is satisfactory and very durable.

J. C. HALBLEIB:—Mr. Libby said that a battery-ignition coil would not deliver the spark. I cannot see why it will not deliver the spark if it is properly constructed. He shows a great loss, the same as the transformer loss, but if he will look over some of the later systems, he will see that improvements have been made that eliminate much of this loss. A poor battery-ignition system or a good one can be built, just as a poor magneto or a good one can be constructed, but if enough value is put into the battery ignition, the same value can be obtained from it as from a magneto.

Speed was mentioned. We know of tests conducted in England and France on engines operating at very high speeds, which were successful with battery ignition and unsatisfactory with magneto ignition. I know of a four-cylinder engine in this country that operates at 3800 r.p.m. with battery ignition, but which failed to operate satisfactorily with a magneto. So I see no reason why the battery ignition, if properly designed, should not do the same work in other instances.

I have been watching truck development carefully of late, and notice that a number of the large manufacturers are changing to battery ignition. This is not on account of the cost, for this is about the same for either battery or magneto ignition. If the coil is properly designed and built, and the generator is right and energy is being stored when the engine is running, the condenser and ignition points should give no more trouble than with the magneto.

C. H. KINDL:—One disadvantage of Mr. Libby's contribution is the indefinite use of the joule heat unit in showing comparisons of ignition apparatus. To say that a certain number of joules is necessary for ignition or to say that a certain type of ignition has more joules in the spark than another means practically nothing. It is the intensity of the energy that is important, or the number of joules per unit of time. An ignition system giving a certain energy in say 0.001 sec. is far superior to a system giving the same energy but spread out over a greater time, such as 0.010 sec. It is only on this basis that the magneto and the battery systems should be compared in regard to sparking energy.

The disadvantage of the battery ignition under cold-weather starting was mentioned, in which case the starting-motor current caused a low voltage on the battery. It is admitted that this condition exists, but it must be remembered that the windings of the battery-ignition system are made of material having a high temperature coefficient of resistance. Hence, in cold weather the resistance of the coil is decreased, which partly compensates for the voltage drop of the battery.

MR. GREIFF:—It has been mentioned that it takes a definite time to charge a coil. I would call attention to the fact that at constant voltage it requires a definite time and that this time must be designed for high engine speeds. If the battery system is designed for high-speed work, it has a coil of very low inductance and at low speed the current drawn is heavy, the draft on the battery is heavy and there must be a design especially for that speed, while a magneto regulates itself, increasing the flow of power to produce the required stream of sparks.

MR. WILSON:—It takes a definite time to charge the magneto circuit as well as to charge the battery ignition-coil circuit. The current builds up in the coil and the flux builds up in a magneto in a similar way. The principle is the same. That is why the cam on the magneto must be designed so that the circuit is closed in advance

to allow it to build up. There is a difference in the advance.

MR. GRIEFF:—The principle is the same in the magneto, however, the voltage is directly proportional to the speed and the time required to build up the current to a given value represents the same angle on the cam; so that, if the cam is right for 200 r.p.m. it will be right for 2000 r.p.m., because the increased voltage requires a shorter time to build up the current.

E. L. CLARK:—I believe the principle is not the same in magneto and in battery-ignition systems.

MR. GRIEFF:—I have used the assumption that the flux is taken out of the winding in a time inversely proportionate to the speed and, therefore, generates a voltage which builds up another current and flux. But one might say that the flux is still there, which is equivalent to saying that the current is built up; however, I think it clearer to say that the principle shown by Mr. Libby does hold. We get higher voltage at higher speeds and therefore the time is reduced.

F. W. ANDREW:—Mr. Wilson, who manufactures both magneto and battery ignition, thinks the coil Mr. Libby showed was not a good one. I have tested practically every ignition device on the market today, and I wish to congratulate the designer of that coil on having turned out the best battery ignition that I have ever seen. It is a fact that he has put more energy into it than is the case with any other coil on the market. This designer has approached a degree of energy which is mainly satisfactory, although it is said that the price is slightly higher than that of a magneto which will do the same work. Regarding this matter of energy, a cigar cannot be lighted with a small flame as quickly as with a large one. A battery-ignition system does have a weak-looking spark. It is evident that as the spark becomes larger it will ignite the gas more quickly. As to the sparks not being in synchronism, we formerly thought synchronism necessary but, from actual tests, some of us have concluded that it is well to have the sparks slightly out of synchronism. Speed was mentioned in connection with battery-ignition systems. I know of an engine that ran 4800 r.p.m., but who wants such an engine? It could not be used economically.

In reference to the resistance coil on a battery, I had something to do with the coil on the first battery systems. It was installed for the low speeds, so that the system would not take too much current and yet give sufficient current at high speeds.

MR. WILSON:—I do not wish to be put in the position of being a special defender of battery ignition. In my remark on the efficiency of coils, I did not mean that the system was not good. Efficiency refers to what is obtained for what is spent. In the early days transformers were built on the same principle, with iron cores and of various capacities, but it took more copper and iron to get the same result. The same is true of the high-tension coil. If enough copper and iron is put into a coil, a given result can be obtained either way. The result can be secured more efficiently with a transformer type of coil.

MR. ANDREWS:—I consider that one of the greatest weaknesses of the battery system has to do not so much with the design or the efficiency of the coil, and nothing to do with the timer, but has to do with the loads, the ground connections from the timer through the coil, and the connections from the coil to the switch and from the switch to the battery. There are usually two connections on the timer, two on the coil, one or two on the switch and one or two on the battery. In addition, there are usually one or two grounds, very often a ground on one side of the coil and a ground on the battery. These are the really weak points of a battery system. They cannot be kept tight.

R. H. KLAUDER:—I am familiar with storage batteries. I know there is enough energy in a battery to ignite the charge in an engine cylinder and, in fact, to ignite the automobile. It seems that the problem is to transfer the energy to the place where we want it. Why cannot the auxiliaries of a battery be designed to do that? It is said that the coil is difficult to design so as to have an efficient magnetic circuit; the inductance is too great. Of course, we know capacity will offset that. Why has not an efficient system been designed that will succeed in getting the energy of a battery where we want it at the right time?

W. R. STRICKLAND:—Battery-ignition systems have been used for some time and the magneto manufacturers have had ample opportunity to present their product for test to determine which system is better. In high-speed and multi-cylinder work a good spark is required and, up to the end of the war, we had not tested a magneto that compared favorably with a battery and a distributor and igniter for high-speed work. One member asks who wants an engine to run at 4800 r.p.m. Many of us want an engine to run at 3200 r.p.m. and, if we wish some assurance at 3200 and 3300 r.p.m., we must run tests up to 3500 and 3600 r.p.m. If there is any superiority in the magneto, those who manufacture it should be able to convince the car builders by practical tests that there is something in its favor.

A MEMBER:—In reference to flame propagation in engine cylinders, why is it that a magneto spark does not need the amount of advance that a battery does, if there is no value to the whiskers on the sparks? It is a well-known fact that a magneto requires only a 15 or 20-deg. advance, while a battery requires 30 deg. If there is no value in the initial heat, why is it necessary to require that extra amount of advance?

MR. WILSON:—We have found only a very small difference in the requirements in terms of degrees at the engine crankshaft. It is clear enough why that is true. It is the intensity of the energy during the first period of the spark that starts the ignition of the gas and, while there may be a few degrees of difference in advance, due to the fact perhaps that the maximum compression comes a little later, it is a very small difference.

MR. ANDREW:—Why is it that battery ignition requires more spark-advance on the segment than does magneto ignition? Also, why do many battery-ignition system manufacturers furnish partial automatic advance?

MR. WILSON:—I believe that is easier to do with the battery ignition. It is easy enough to give the advance desired. The magneto must be designed for a definite advance. That is the real reason why battery ignition is furnished ordinarily with more advance, so that the user can have whatever he desires.

MR. STRICKLAND:—The reason for the automatic advance is to allow ease of driving; there is no need to worry about it. In driving with a magneto, the spark must be changed at a hill or when slowing down for a hard pull.

E. T. BIRDSALL:—I drive a car with an engine running up to 3000 r.p.m. It has battery ignition, the cheapest on the market. I have bought many hundreds of them and have never had much trouble, except on this one particular car. The interrupter springs are broken on account of the high speed. But as far as the spark-advance is concerned, the spark lever has been at almost full advance during all the two years that I have had the car.

I have never had the engine kick back in starting, it does not overheat and will run from 5 to 50 m.p.h.

MR. GRIEFF:—The fact of operating a car with fixed ignition for two years should be noted by those who claim the pressing necessity of timing ranges sometimes approaching 180 deg. The breaking of springs refers back to the construction of the interrupter. We have very little such trouble.

MR. BIRDSALL:—Is it then simply because of poor-quality springs?

MR. GRIEFF:—We are asked why we cannot get enough energy to obtain 10 or 15 milli-joules at once with a battery that can deliver about 1 hp. in starting an engine, and why we cannot make capacity neutralize the inductance of the coil. Unfortunately, the capacity does not neutralize the inductance in this case, as we have a continuous and not an alternating electromotive force; therefore, the rate of building up coil energy depends simply upon the electromotive force, and a magneto having an electromotive force proportional to the speed builds up the requisite spark energy at all speeds.

A. D. T. LIBBY:—If one has no idea of the operation of a magneto that gives a battery-type spark and no follow-up, clamp one on a truck. There is a vast difference between a magneto with a weak spark and a magneto with some backbone in it. I have noticed that all those who have ignition systems with the initial impulse, which drops off later, are the ones who say that not much heat is needed, and that the reserve we have in the magneto is not required. That reserve heat is needed, as I have shown by curves and test. It is hard to contradict evidence of this character. It is true that when an engine has a perfect mixture and it is hot, it can be run on a surprisingly small amount of energy. That is not the story. It is the problem of starting, of burning both weak and rich mixtures, and of the amount of advance. The battery men admit that at higher altitudes they must have a greater advance. Why? Because the mixture has become thinner due to the less dense air. One of the makes requires a 56-deg. advance. The battery men require a long time to burn the fuel. As I said at first, the battery and the magneto systems are different in operation. I take exception to Mr. Wilson's statement that the flux is there. The rotation directs the flux to get a quick change through the coil, and there must be an opposite circuit; otherwise the coil will be slow. With the magneto there is a rotating element with a force that is already there, with the magnets to shove it through in the other direction. A time rate of change that is beyond the battery coil is obtained. The short-circuit value is about 6 amp.; the actual current rise was 3.2. It follows closely the theoretical curve. That is why not as much energy can be obtained from the battery coil. A compromise in coil design must be made. In connection with the comparative spark-advance of the battery and the magneto, I gave two illustrations, one on the Liberty engine. The battery required a 35-deg. advance. The magneto under the same conditions had an advance of 24 deg., yet the gas consumption was lower and the engine had greater horsepower.

Regarding comparative tests of battery and magneto systems, I am sure the magneto manufacturers are ready to cooperate at any time. Summing up the whole proposition, either system works. My contention is, as I have pointed out theoretically and practically, that for all ranges, all conditions of temperature and mixture, general all-around running day after day, dependability and reliability in every respect, it is impossible to excel the magneto for the best service. Its spark is hotter; that is the reason the magneto excels; that is, its flexibility. As the speed increases, the heat of the spark goes up with it. Gas cannot be burned without heat.

STANDARDIZED LUBRICANT SPECIFICATIONS

THE Government Committee on the Standardization of Petroleum Specifications has adopted methods of testing lubricants and uniform specifications which became effective April 16. These are covered in Bulletin No. 4 of the Committee which has recently been issued. It is pointed out that heretofore specifications for lubricants have been drawn up by the various departments and agencies purchasing them and the Committee has found it possible to coordinate and standardize these specifications, to eliminate some tests of doubtful value and to simplify and harmonize the wording. The specifications as now drawn up, it is thought, will eliminate oils that would prove unsatisfactory in service and yet at the same time allow the refiners great latitude in their choice of crude oils.

Methods of testing lubricants with regard to the flash and fire points, viscosity, pour test, cold test, acidity, carbon residue, emulsifying properties, corrosion, evaporation, precipitation and the wick feed test are included, together with the revised viscosity test of the American Society for Testing Materials, which was received after the Committee had completed its work. Specifications for three grades of lubricating oil and oils for aircraft machine guns, recoil and recuperator cylinders on gun carriages, steam cylinders of noncondensing engines, polishing floors, cleaning guns and lubricating ice machines, stationary-cylinder aircraft engines and motorcycle engines and marine engines are given, together with specifications for cup grease, transmission lubricant, gear chain and wire rope lubricants and the oil and grease used in the recoil mechanism of the 75 and 155-mm. gun carriages.

Copies of the bulletin containing these specifications can be secured from the Bureau of Mines, Washington.

AMERICAN FARMING

THE American farmer produces four times as much food per human unit as the European; he replaces three men by using horse or power-driven machines and lessens the cost so materially that during the war he fed not only America but much of the rest of the world. Had it not been for plows, harrows, rollers, cultivators, seeding machines, wagons and trucks, tractors, hay-making tools, harvesters, threshers, gas engines, diggers, dairy machines and appliances and hundreds of other tools and machines, the production of our farms would have been the human production of Europe, or but one-fourth of the output.—Prof. C. W. Burkett.

The Fuel Problem from the Refiner's Viewpoint

By R. L. WELCH[1]

SUMMER MEETING ADDRESS

WHETHER the gasoline or internal-combustion engine fuel supply will be adequate to meet future needs lies more in your hands than in the hands of any other interest or persons. The problem of the hour is to conserve fuel. If automotive engineers can achieve this result by redesigning engines, they will be doing a great thing for the automotive and oil industries and for the public. The shortest and most direct way of presenting the actual gasoline situation is to show how the supply of crude oil has been diminishing in relation to the demand. In 1911, the oil industry had to supply gasoline for only 700,000 automobiles. In other words, from the supply there were 314 bbl. of domestic crude oil available for each automobile. Last year, however, there were only 50 bbl. of domestic crude oil available for each automobile in use in the United States. If the number of cars which are predicted are actually produced, and if the production of crude oil does not increase any more rapidly than it has in the past, in 1920 there will be available per car 40 bbl. of crude oil. In 1921, if the predictions of your statistician that there will be 12,000,000 cars registered is correct, unless oil production increases more rapidly than it has in the past, this country will provide only 35 bbl. of crude oil per car.

Yet I believe that the gasoline problem will be solved; that the necessary gasoline will be available. There will be local shortages on account of transportation. It will probably be true that during certain seasons there will be acute conditions just as there are certain acute conditions in the country at present. However, the gasoline problem will not be solved unless everybody who has a direct relationship to it cooperates in the solution. Those who are most interested are (*a*) the Government of the United States which must cooperate with the oil business and with the automotive engineers at home and abroad, (*b*) the greatest possible efficiency must be gotten by the automotive industry in the consumption of engine fuel and (*c*) the oil industry must be more efficient and must get more gasoline from each barrel of crude oil.

Here is a sample of the reports which are current. From a recent paper I clipped a statement which emanated apparently from some sales manager of an automobile company.

> The hue and cry about depleted fuel fields and the necessity for conservation, with the attending rise in prices, will be a boomerang that will hit the oil interests when they least expect it.

That is a good text. The consumption of crude oil, gasoline and in fact of all petroleum products in the United States since Aug. 1, 1919, has been unprecedented and tremendous. The best way to understand that is to consider the consumption in 1919. I am speaking of domestic production and domestic consumption. In the entire year of 1919 we consumed 375,000,000 bbl. of oil in this country; domestic production. The latest Government figures show that in April 1920 we were consuming at the annual rate of 452,000,000 bbl., instead of at the former rate of 375,000,000 bbl. During January 1920 consumption was at the rate of 409,000,000 bbl.; February, 429,000,000 bbl.; March, 439,000,000 bbl.; and April, 452,000,000 bbl. The decided increase is thus evident. Furthermore, if the number of automobiles increase, these oil consumption figures will increase. The change in prices which recently occurred was by reason of the change in the relationship of production to consumption, which took place about Aug. 3, 1919. I will again state the fact that in 1919 we consumed 375,000,000 bbl. of crude oil. From Aug. 1, 1919 to March 1, 1920, we have been consuming oil at the rate of 436,000,000 bbl. per annum and we have been producing at the rate of 402,000,000 bbl. per annum. This means an excess of consumption over production of 34,000,000 bbl. That, briefly, is the whole story from the aspect of production and consumption.

I will now reply to three questions relating to quality, quantity and price, which your General Manager recently sent to the American Petroleum Institute.

Question: With the appended predicted production of automotive apparatus for the next three years, can you state that the gasoline end-point will not exceed 440 deg. fahr. on or before Jan. 1, 1922, or can you tell whether it is possible to hold this limit until Jan. 1, 1923? With this specification, will it be possible to keep 140 deg. fahr. as the initial boiling plant?

Answer: No reasonably well-informed man likes to make predictions about the oil business. At the same time the logic of the situation is such that if I were an automotive engineer, I would plan to use and conserve the present-day fuels. The only fuels possibly available aside from the present-day engine fuels are kerosene and perhaps a distillate similar to the fuel which is used in Diesel engines, that is something approximating gas oil. Gas oil and kerosene are tending to become as scarce as gasoline. At the present time many gas companies in the United States are in distress for gas oil. It has more than doubled in price in a comparatively short time. The demand for kerosene has been so great that the tank-wagon market price of kerosene throughout the country is approximating two-thirds of the tank-wagon market price of gasoline. A short time ago it was about one-half. This increasing demand for these heavier distillates is a demand which will apparently continue and which must be met, because we must never forget that the kerosene lamp is a long ways from being supplanted, and that the demand for gas oil will continue to be very great.

The price of kerosene and gas oil is rising more rapidly than the price of gasoline. With the great demand for these two products I do not see where the kerosene will come from to enlarge the fuel supply; and, if the kerosene or gas oil is available, it seems obvious that by efficient refining methods it will be cracked into gasoline approximating in its boiling points the ordinary grades of fuel in use throughout the country. If you design your engines to use these two heavier fuels, it looks as though the oil industry were going to beat

[1]General secretary, American Petroleum Institute, New York City.

you to it by cracking both of them and making gasoline out of them.

Question: With the stated production of automotive apparatus, does it appear to you that it would be impossible to furnish fuel for the growing use of the apparatus?

Answer: I believe that it will be possible to furnish that fuel provided we have the cooperation of everybody who has a proper relationship to the problem. I do not believe that it will be solved unless we have that cooperation. If the Government of the United States will cooperate with the oil industry, the same courage and the same business ability which have characterized the automotive industry and the oil business will get the oil, in my judgment.

Question: Will the price of crude oil and of petroleum products generally take a course independent of general commodity prices, or will the price of these follow the rise and decline in commodity prices and labor?

Answer: I do not know.

The Discussion

F. E. Moskovics:—How about shale?

R. L. Welch:—There is, as yet, no practical commercial method, as I understand it, whereby gasoline and crude oil can be obtained from shale. There are vast quantities of oil in shale. There are other vast petroleum deposits in the world which, sooner or later, in my judgment will, through the ingenuity of man, yield petroleum and gasoline. The general opinion among oil men is that as yet nobody has evolved the process whereby crude oil and gasoline can be gotten from shale on a commercial basis.

J. G. Vincent:—Are you in a position to discuss for a moment the so-called casinghead gasoline? What is the probability of increased production or increased use of that type of fuel?

Mr. Welch:—Casinghead gasoline will be increasingly used. We must use it. It is a good product and the only problems in connection with it are, first, safety in handling it; if it is properly blended it is as safe as any gasoline. Second, it occurs in many instances that casinghead gasoline is improperly blended with kerosenes or other heavier fuels. In such instances the problem of the user or the engine designer is a difficult one and, of course, when there is such a tremendous strain upon gasoline consumption as at present, the tendency on the part of many dealers is to take a carload of casinghead gasoline and mix it with something which is too heavy or which is improperly blended.

H. M. Crane:—You have brought out a point which carries much weight. We see daily the same lack of efficiency in the distribution of the fuel supply, due to dealers who wish to profiteer for one reason or another and who wish to sell as gasoline material which is far below the standard of the well-known refineries. The car of casinghead plus the car of kerosene is a dead waste to everybody when it is mixed that way and it cannot be successfully handled by automotive engineers. Can the petroleum industry take a hand in correcting that form of abuse which has been widespread in this country for the last ten years?

Mr. Welch:—I do not know how widespread the abuse is. My thought about the matter is that the recent investigation by the Bureau of Mines of about sixty samples taken indiscriminately throughout the country show that the abuse is very small. I may be misinformed. I think that here and there some gasoline of the character you have in mind is sold. That practice should be stopped. The great trouble is that such abuse has led to the adoption of inspection statutes which have not worked to the advantage of the public. For example, Oregon adopted an inspection statute and was forced to abandon it very recently. The companies on the Pacific coast simply could not furnish the gasoline which was demanded by the inspection statute of the State of Oregon. The Governor issued a proclamation and told the oil companies to sell in Oregon the same sort of gasoline they were selling in California. The difficulty is the practicability of controlling those situations without getting an outlandish or ridiculous standard. My own judgment is that in the long run the consumer will determine that question. His own discrimination will be sufficient. He will go to reliable and reputable companies and get reliable gasoline. That is the solution.

R. W. A. Brewer:—What percentage of crude oil is treated out and cracked?

Mr. Welch:—I am unable to state an accurate figure on that offhand. I will say that much more can be cracked than is cracked at present. In other words, I believe that more cracking plants will be put into existence than are in existence at present. This has come on suddenly, but it is not great. By the time the people who have the crude oil install the cracking plants, I fear that the automotive will be considerably ahead of the oil industry.

Mr. Brewer:—You asked automotive engineers to cooperate with the oil men. Would you state a few ways in which they can do that?

Mr. Welch:—From an engineer here present, I heard the statement that a certain automobile company could make its car run 30 miles on a gallon of gasoline, if the car were properly equipped. Is not that the answer?

Mr. Brewer:—I do not know whether you mean that the automotive engineers should make smaller machines or that they should take action with the Government to restrict the consumption by any individual user or maker of cars.

Mr. Welch:—Speaking as a layman, it seems rather absurd that we require so much power in our cars. It appears ridiculous, in going down Michigan Boulevard for instance that people require 50 to 80 hp. to go 20 m.p.h.

C. M. Manly:—What has been the effect upon the gasoline situation of the rapid extension of the burning of oil in steam plants? Why is it that there is such a tendency at present for the substitution of petroleum for the generation of steam on railroads and in the Navy, under this petroleum stress?

Mr. Welch:—It is both our misfortune and our fortune that fuel oil for the uses you mention is so much more efficient than coal, everything considered, that the demand for fuel oil has been growing enormously. We have had a complete reversal in that situation. The question only emphasizes the fact that we never know what to expect in the oil industry. In 1918 and the early part of 1919, I represented the independent refiners of the Mid-continent field. At that time the price of fuel oil was so low, after the armistice, when the allied navies stopped using it and during the commercial depression which followed, that I heard one man say it was as desirable to own a skimming plant, which is a plant producing gasoline, kerosene and fuel oil, as to own a saloon

during prohibition. His reason was the prostration of the fuel-oil market. Commercial plants all over the country then began using fuel oil and there was a revival of the industry.

There has been a great scarcity of fuel oil, and prices have risen from $1.25 to $3, and more, per bbl. The consequence is that nobody knows what the price of fuel oil will be if present conditions continue. If the consumer selects it, he selects the article he intends to use and names the price. The producer does not name the price. Prices in general are determined in this country by the consumer. If anybody here thinks that oil prices are controlled by combination, collusion or monopoly, I would like to talk to that man, because it can be demonstrated that he is wrong. I just heard some one say that everybody has the opinion that prices are thus controlled. There never was a time in the history of the oil business when there was so much competition as there is today. There is today more competition in the oil business, I believe, than there is in the automotive business. There is no business in the world in which there is more free and independent capital flowing than into the oil business. Has any one ever heard of a man who hesitated to get into the producing, the refining, transporting or selling end of the oil business because of the fear of monopoly, of collusion, or of being driven out of business, within the last five years?

MR. MOSKOVICS:—How about distribution?

MR. WELCH:—The same is true in regard to distribution. There are hundreds of men who have gone into the jobbing business within the last five years. I happened to represent the jobbers of the West for about two years. They were unfortunate enough to ask me to represent them at a time when they thought they were being driven out of business. At the first convention we drew mournful pictures of what was going to happen to the jobbers. Some time later we had another convention; a greater number of jobbers were there and they had more stations, more gasoline and more business. The same thing occurred later. Finally, we had another convention and had to hire a hall. Certainly something else must have been happening to them besides being driven out of business. That is the answer throughout the United States. Of course it is true that with a commodity which is limited in quantity the competition for it becomes great, and it becomes difficult for us to get it. There are many jobbers in the petroleum business today, just as there are many refiners, who are finding it difficult to get supplies; but let me say that there is not an oil company in this country today that, so far as supply is concerned, is not having difficulties. There is not a Standard Oil Co. office in this country where they do not have the same problem that the independent oil companies have to obtain crude oil with which to do business.

In 1911 the Standard group refined 80 per cent of the petroleum refined in the United States. In 1915 this group refined 60 per cent of the petroleum produced in the United States. In 1919 the same group refined only 49 per cent of the crude oil refined in the United States. These figures are the official figures taken from the Government reports. In 1919, for the first time in the history of the oil business, the independent oil companies refined more crude oil than all the affiliated Standard Oil companies. Is that competition? One of the reasons for present prices is the fierceness of the competition. An oil well cannot be drilled anywhere without a crowd of purchasers of oil being on hand to buy the oil.

B. B. AYERS:—How much of the present price of gasoline is due to abnormal exports?

MR. WELCH:—That is a pertinent question in view of the fact that the Federal Trade Commission suggested that Congress ought to consider the question of putting an embargo upon gasoline. I will refer to its official report. In 1919 there were only 372,000,000 gal. of gasoline exported; that is a small fraction of the total. The Standard Oil Co. of Indiana alone, I presume, will sell double that quantity of gasoline in the Middle West, or close to it this year. If we should place an embargo on the exportation of oil products at a time when we are an importing nation, when we must rely upon Mexico, Mesopotamia, Persia, Russia and other countries to get petroleum products, would it be sound business policy waiving all constitutional objections and all other facts in the situation? Do we want to place an embargo upon a commodity that we really must import?

MR. BREWER:—What percentage of oil do we import?

MR. WELCH:—I cannot give it in terms of percentages, but at present we are using more than we are producing and the importations from Mexico are increasing very rapidly. Up to the last two or three years, broadly speaking, we were practically balancing on our exports and imports; not in terms of specific commodities, but the total. At present, however, we will be obliged to import vast quantities of oil.

MR. BREWER:—Does the bulk or the price balance?

MR. WELCH:—I was speaking of bulk. At present we are importing much more than we did in the past. We are importing more oil from Mexico than ever before.

MR. BREWER:—Is more being imported than is being exported in gasoline?

MR. WELCH:—Yes, that is my judgment, considerably more, when one takes into consideration the potential gasoline content of the crudes imported. A large part of the Mexican oil which is coming in is what is known as Panuco crude, which is low in gasoline content; but my judgment is that at present we are importing more gasoline, all products considered, than we are exporting. I may be wrong about that, but I think I am right. I am certainly not wrong about the future.

H. L. HORNING:—In connection with this subject, for a year and a half I have been conniving with Mr. Clarkson and with members of the National Automobile Chamber of Commerce committees to propound questions for the Petroleum Institute to answer. We have gone a long time before we have got an answer, but today two of the greatest industries in the country have met face to face; the questions of one have been put to the other and have been answered.

Regarding prices those who have studied economies must understand that with such great oil shortages the price of oil must go up. To take a pound of bread, representing a certain general cost, to a gasoline filling station and exchange it for gasoline, illustrates the relationship which we must understand and realize. It is not the dollar relationship; its value is in the amount of gasoline received in exchange.

I believe I am correct and just to the petroleum industry when I say that gasoline is cheaper, relatively, than bread. Therefore, I cannot help but feel that its value must increase until the price somewhat controls the output of automotive apparatus. As a man who has worked a long time to get this answer I wish to thank Mr.

Welch and to say that I believe this session has proved most important, from a vital standpoint, because he has answered the three questions that we wanted to know.

MR. WELCH:—On this question of price, the question was

> Will the price of crude oil and petroleum products generally take a course independent of general commodity prices, or will the price of these follow the rise and decline in commodity prices and labor?

That is a complicated question, because it ties a number of prices together. However, I have expressed my opinion on petroleum, and here is a memorandum which was submitted to the Federal Trade Commission recently, in which I said

> The low reserve stocks of the country have been and are being dangerously depleted, and further advances will probably ensue unless production increases or consumption decreases, because the latest figures demonstrate conclusively that an equilibrium between supply and demand has not been reached. Furthermore, the recent advances in crude have not as yet been fully reflected in the prices of refined products.

As to my judgment in regard to oil prices, I believe they will advance because of the intrinsic value of the article. When I pay 30 cents for a linen collar I feel as though gasoline at 30 cents is not very high. I do not need to tell you anything about the intrinsic value of gasoline. The intrinsic value of gasoline has never been reflected in the price. We have had the most valuable product imaginable available for our use and it has been available in abundance up to a very short time ago, but I believe that unless we get more of it, unless new fields are developed, we are reaching the point where the price will induce the average motor-car user to conserve gasoline who never saved gasoline. Why have they not saved it? It has been too cheap. Nobody thought it was an element in the cost of running a motor vehicle.

G. A. GREEN:—Who is it that settles the price, and how is an increase in price arrived at?

MR. WELCH:—The price is settled by the consumer and the demand and the supply. What determines the scale of automobile prices throughout the United States? It is competition. There is no person or group of persons who can sit anywhere and control any of these prices. The price of crude oil is the determining factor. The price of crude oil went up before gasoline did. The price of crude oil ascended, and that was brought about by competition. Gasoline has not advanced anywhere near as rapidly as crude oil in price.

P. J. DASEY:—What per cent does gasoline have in relation to the crude? You stated that a certain amount was taken out of the ground in 1919. What percentage was gasoline?

MR. WELCH:—As I remember, in 1919, the amount of gasoline was 23 per cent. In 1918 it was slightly less.

MR. DASEY:—Is that based on a production of 450 deg. fahr. end-point gasoline?

MR. WELCH:—No; I believe no one could give an absolutely accurate figure in terms of boiling point.

MR. DASEY:—Is the cracking process gradually coming into use? What percentage of distillates suitable for cracking would be available?

MR. WELCH:—That would involve considering each crude oil of the United States and a complicated delving into figures. From the average grade of Mid-continent crude oil, 50 per cent of gasoline can be obtained.

MR. DASEY:—Does that include the first run or just the cracking?

MR. WELCH:—All of it, the total quantity. I think that 50 per cent is a fair figure for Mid-continent crude. I base that solely upon the opinion of competent oil men with whom I have talked. That includes the average grades of Kansas, Mid-continent and Northern Texas crude oils.

GEORGE T. BRIGGS:—How does California crude oil run?

MR. WELCH:—They are not cracking oil in California, but cracking plants will be put in there. It has not been necessary, up to a short time ago, to crack oil in California.

ALFRED REEVES:—At many of our meetings it has been said that the matter of price rested largely upon the matter of production.

MR. WELCH:—Except where there is a slack demand, I do not regard the fluctuations in the stocks of gasoline as being particularly important. Where the demand is slack there may be a temporary recession in price in various localities, not justified by general conditions, because of the fact that gasoline is a liquid commodity and the storage facilities are therefore limited. You cannot pile it up like so many cords of wood. But where consumption is equal to or greater than demand, the fluctuations in the stocks of gasoline are not particularly significant. These stocks are mere working stocks. It is the supply of crude which cuts the figure. The available storage of gasoline is very small in comparison with the demand. You will find that if we relied upon our storage stocks of gasoline, even when they are the largest, we would be living a mere hand-to-mouth existence.

MR. REEVES:— Can you give any information as to the tendency of oil companies to put in cracking processes?

MR. WELCH:—Some of the oil companies have cracking processes that are idle because they cannot get the product to crack. On the other hand, companies which have crude oil available are putting in cracking processes, and undoubtedly there will be more gasoline cracked in the future than in the past. Do not think it is a mere question of capacity. There is a fundamental shortage of crude oil. There is also a question of efficiency. It may be that fuel oil that contains gas oil is being burned when it ought not to be.

THOMAS MIDGLEY, JR.:—Why cannot the gas oil be taken away from some of the gas companies?

MR. WELCH:—In the first place that is being done and in the second place it ought not to be done at once.

MR. MIDGLEY:—Yes, it ought to be done. That gas oil ought to be sold on a thermal basis.

MR. WELCH:—It is correct that candlepower standard ought to be abandoned so far as gas is concerned. However, it cannot be abandoned instantly. A joint committee of the American Gas Association and the American Petroleum Institute is at work attempting to solve this problem and to reduce the amount of gas oil to be used by gas companies. It requires new investment, and the gas companies are in a very critical situation. The public's motor cars are competing with their kitchen ranges and as long as this is true they must pay the penalty.

MR. BREWER:—Is it not a fact that they have abolished the candlepower standard in England?

MR. WELCH:—I do not know. They ought to do so. I think it will be abandoned sooner or later here. I suppose gas was originally used for light rather than for heat. It takes about half a century, under progressive American institutions, to reverse that process.

MR. MIDGLEY:—Ought not we help the gas companies?

MR. WELCH:—We are doing everything that we can, everything within our power, both by furnishing the oil and by their raising the price.

Aluminum Alloys

By Zay Jeffries[1]

Detroit Section Paper *Illustrated with* Photographs and Charts

IRON ranks first, of all the metals. It is unthinkable that any other metal will even approach iron or steel in importance in our generation. Copper, lead and zinc come fairly close together in tonnage, but we think of copper as being next in importance because it is higher-priced. Tin ranks next, with slightly greater tonnage than aluminum, and aluminum is fifth of the non-ferrous metals.

The place of aluminum in the automotive industry is indicated in Fig. 1. The curve for aluminum shows a continuous increase, but there is a drop in the motor vehicles curve, in 1918, caused by the Liberty engine production; that is, the aluminum which would ordinarily have gone into motor vehicles was thus used. If automotive or gasoline engines had been considered in Fig. 1, this curve would have shown an increase also. It is evident, therefore, that the use of aluminum and the advance of the automotive industry are parallel; and they should be, because the automotive industry uses more

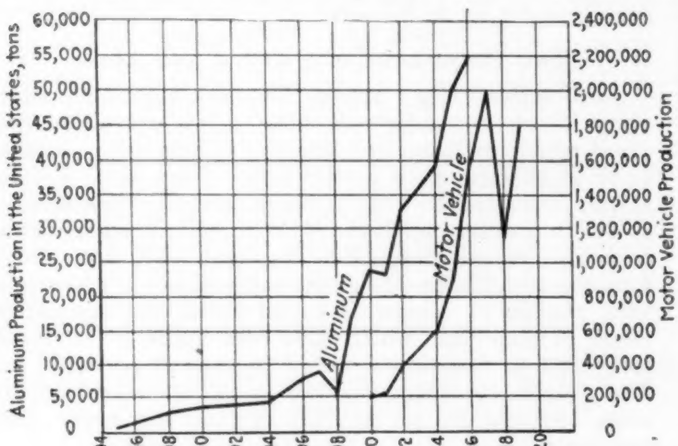


Fig. 1—Production Curves of Aluminum and Motor Vehicles

aluminum than any other. It is safe to say that the automotive industry uses well over 100,000,000 lb. of aluminum per year.

Fig. 2 shows curves for the production of copper and aluminum, drawn on a logarithmic scale so that instead of the ordinary curve they approach straight lines. This goes back to 1855 on copper and starts with 1890 on aluminum. It is a fact that the production of copper on this logarithmic scale from 1855 to the present is practically a straight line. From 1890 the aluminum line is practically straight, and is very much steeper than the copper line. The two lines would intersect about 1935, if carried forward in the same way. We might bear that in mind and see how well these statistics are borne out.

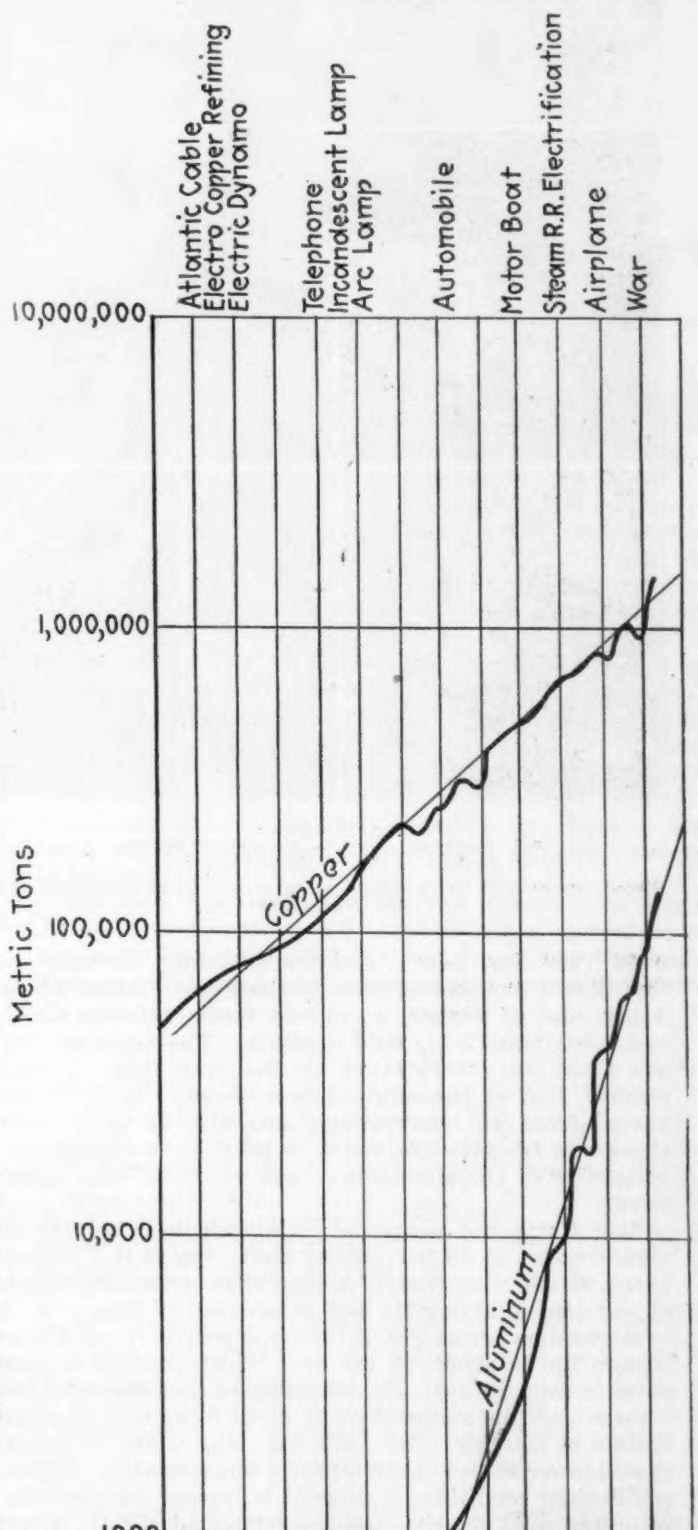


Fig. 2—Production Curves of Aluminum and Copper

Metallography of Aluminum Alloys

When copper is added to aluminum the compound $CuAl_2$ is formed, as shown in Fig. 3. This dissolves in solid aluminum up to about 4 per cent copper at 500 deg.

[1]M. S. A. E.—Research director, Aluminum Manufactures, Inc., Cleveland.

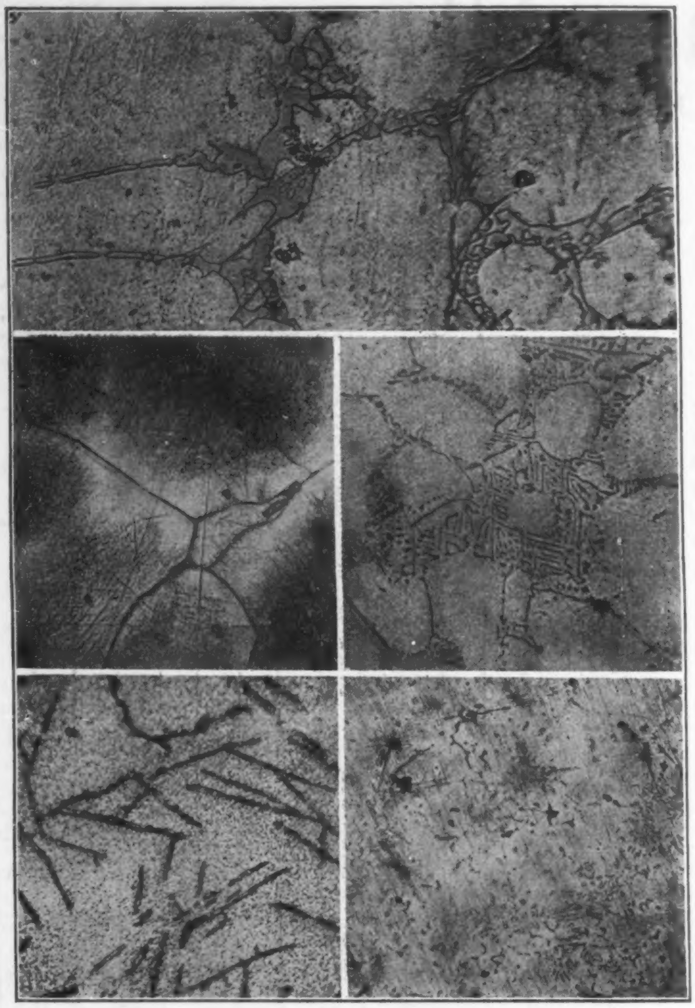


Fig. 3—Copper
Fig. 4—Zinc Fig. 5—Magnesium-Silicon
Fig. 6—Iron Fig. 7—Zinc Copper

PHOTOMICROGRAPHS OF VARIOUS ALUMINUM ALLOYS MAGNIFIED TO 250 DIAMETERS

cent. (932 deg. fahr.), and the solubility decreases to less than 1 per cent at room temperature. Above about 4 per cent of copper, a eutectic forms between $CuAl_2$ and aluminum-$CuAl_2$ solid solution. The tendency for the $CuAl_2$ to separate out in the free state is very marked, that is, the solid solution seems to be easily divorced from it. The variable solubility of $CuAl_2$ with change in temperature makes it possible to change the properties of the aluminum-copper alloys by heat treatment.

Zinc forms the compound Zn_3Al_2 which is soluble in aluminum up to 40 per cent of zinc. Fig. 4 is a micrograph at 250 diameters of a cast alloy containing about 85 per cent of aluminum and 15 per cent of zinc.

Magnesium forms Mg_4Al_3 which is soluble in solid aluminum up to about 13 per cent of magnesium at the eutectic temperature. The solubility of the compound decreases with the temperature to about 5 per cent of magnesium at 300 deg. cent. (572 deg. fahr.), and probably to still lower values at atmospheric temperatures. Under equilibrium conditions a eutectic is formed between the saturated solid solution and the compound Mg_4Al_3, when the magnesium content exceeds 13 per cent. Under normal conditions of cooling in sand, the eutectic is formed as a network around the grains when the magnesium content is over about 6 per cent. Magnesium also combines with the silicon present in commercial aluminum, forming the compound Mg_2Si. This compound is very brittle and renders the metal containing it in excess brittle. (See Fig. 5.)

Iron, manganese and nickel, form $FeAl_3$, $MnAl_3$ and $NiAl_3$ respectively. Fig. 6 shows the structure obtained by adding 3½ per cent of iron. These constituents are very slightly soluble in solid aluminum and separate out in the form of needles when more than 0.5 per cent of any of the elements is present. The $FeAl_3$ needles have a strengthening effect on most aluminum castings by virtue of the fact that the normal eutectic network is made less continuous. As the fracture in nearly all aluminum castings takes place at the eutectic network, the $FeAl_3$ needles make the path of rupture greater and hence increase the breaking load. By increasing the breaking load more deformation is forced upon the more ductile excess material, thus producing a higher elongation. Iron in amounts up to 1.5 to 2 per cent may therefore be quite beneficial in aluminum castings.

Fig. 7 shows the effect of adding 2.75 per cent of copper, 7 to 8 per cent of zinc and about 1½ per cent of iron. The iron needles form in various places. $CuAl_2$ is also formed and 7 to 8 per cent of zinc is present without forming a complete network. This alloy is both strong and ductile, having an average tensile strength of 27,000 lb. per sq. in. and an elongation of 4.5 per cent when cast in green sand in the form of a test-bar about 0.5 in. in diameter.

THE PHENOMENA OF GROWTH AND AGING

Some queer things happen in these aluminum alloys about which we knew very little a few years ago, and about which we know comparatively little now. But we know much more than we did a few years ago. For example, referring to Fig. 3, no matter how this alloy is cooled in ordinary methods of production, upon reheating to a temperature around 300 deg. cent. (572 deg. fahr.), a permanent change of volume takes place. This permanent change of volume is found in all the commercial alloys of aluminum which have been studied. It differs somewhat in magnitude, but it is present in every one. The change in volume can be made permanent at the room temperature so that the casting can never grow any more.

The first place where this came to my attention was in connection with racing-car pistons, where the temperature had been very high and the pistons had actually increased in diameter. Like a great many other things it was at first considered skeptically, but there is absolutely no question about it now. It is not an important factor in the ordinary water-cooled engine, because the temperature is seldom high enough to cause growth, except perhaps in the head, where the clearance is ample to take care of the growth. But in air-cooled cylinders and in racing engines, there is no question that the pistons are susceptible to a certain amount of growth.

Other things are encountered in aluminum alloys that have been happening to all the alloys used in motor cars since the industry began, but which we did not know much about until recently. When aluminum alloys cool to room temperature, they keep on changing in physical properties at that temperature. The old standard No. 12 alloy, for example, when cast in sand, has a certain tensile strength and elongation; but 24 hr. after casting it has different properties. Its strength has increased slightly, and its ductility has decreased slightly. After a few months the change is still more in the same direction. In one of the more ductile alloys, a reduction in

elongation from 8 per cent in the freshly-cast alloy to 5 per cent after a month's aging is sometimes found, while the tensile strength and elastic limit increase.

All of the castings that have been used in the last fifteen years have been undergoing this change, which is nearly complete in thirty days at ordinary room temperatures. No serious disadvantages have arisen, so that the fact that we know now that these changes take place should not cause alarm. It may lead a little later to a more intelligent use of material in places where these changes might possibly be accompanied by a slight change in shape, or even a change in volume.

Effect of Alloying on Physical Properties

The unique effect of zinc in increasing tensile strength is indicated in Fig. 8. Starting with pure cast aluminum with a tensile strength of 13,000 lb. per sq. in., copper is added in various amounts, as shown. The tensile strength increases according to the curve shown in Fig. 8. Nickel forms the compound $NiAl_3$, which has proper-

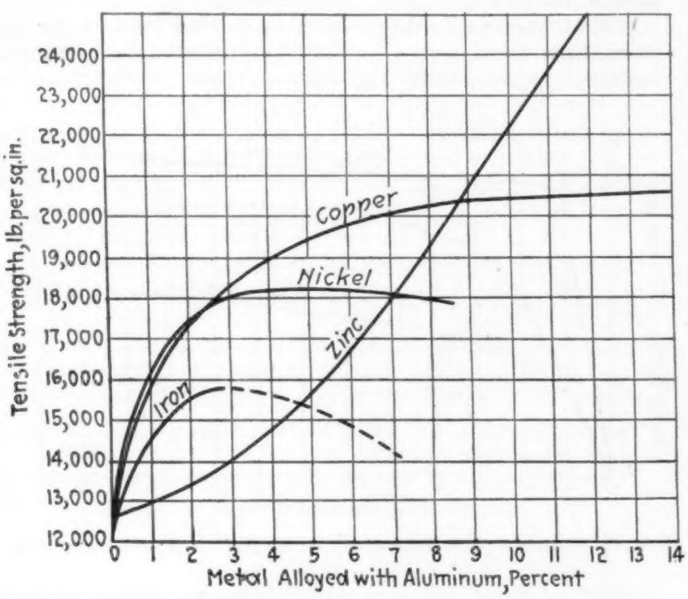


Fig. 8—Effect of Various Elements on the Tensile Strength of Aluminum

ties somewhat like iron, but it is more soluble in aluminum than $FeAl_3$. Iron reaches a maximum tensile strength at 2.5 per cent, whereas nickel shows a maximum at about 5 per cent.

The addition of zinc presents an entirely different type of curve from those of the other elements considered, because it forms a different structure. The tensile strength increases gradually up to 12 per cent of zinc as shown in Fig. 8, and, although not shown on the curve, the strength increases up to 35 per cent of zinc. We have made a set of cast test-bars with an aluminum-zinc alloy containing a little iron, which averaged over 50,000 lb. per sq. in. tensile strength. We do not consider this a good alloy because it is brittle and the specific gravity is over 3.3, whereas all the other alloys mentioned are under 3.0. A high zinc alloy of this kind is in general unsuitable for engineering uses.

When the effect of these same elements on ductility is measured by the percentage of elongation, zinc is again seen to be in a class by itself. It is evident that copper reduces ductility faster than any other element. The addition of iron is not very practical above 2 per cent,

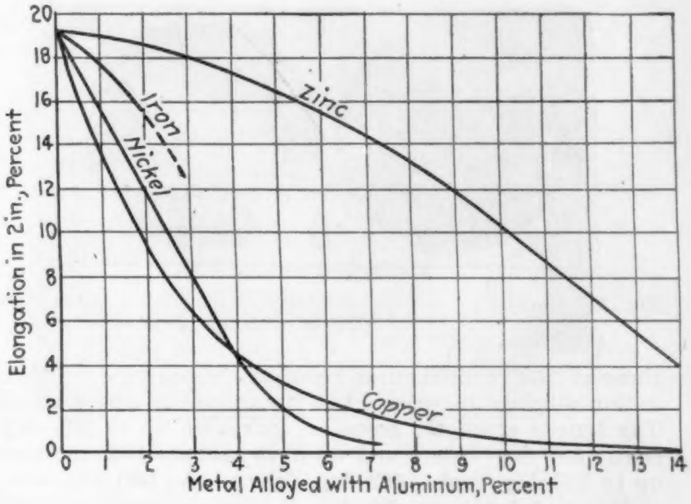


Fig. 9—Effect of Different Elements on the Elongation of Aluminum

while nickel produces about the same result as copper and costs more. The addition of zinc does not decrease the ductility of the castings as rapidly as any of the other elements.

Fig. 10 represents the effect of temperature on two different types of alloy. The tests were made at the temperature indicated. Consider the alloy represented by the dotted lines. This is a strong alloy known as Lynite 145. It contains about 2.75 per cent of copper, 7 to 8 per cent of zinc and over 1 per cent of iron. It has a high tensile strength at ordinary temperature, say a little above 0 deg. cent. (32 deg. fahr.). In this particular sample it was 28,000 lb. per sq. in. and the elongation was about 8 per cent. In testing it with a rise in temperature it is found that its strength decreases regularly up to 300 deg. cent. (572 deg. fahr.), at which temperature it is slightly under 9500 lb. per sq. in. On the other hand, its elongation increases rapidly with an increase in temperature.

The alloy represented by the full line contains about 12 per cent of copper and about 0.75 per cent of manganese. The addition of the manganese has the function of making this alloy stronger at temperatures above

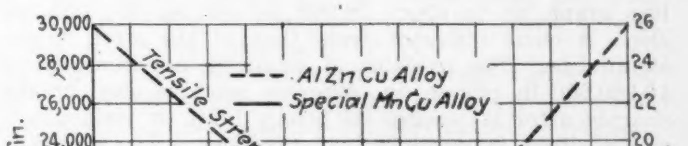


Fig. 10—Effect of Temperature on the Strength and Elongation of Two Aluminum-Base Alloys

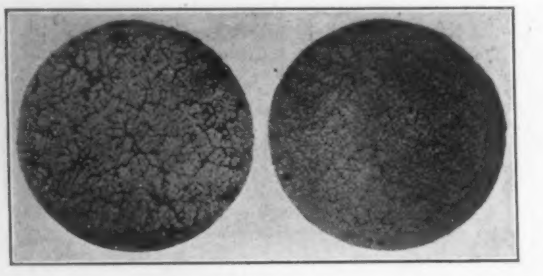


FIG. 11—PHOTOMICROGRAPHS OF A SAND-CAST AND A CHILL-CAST PISTON ALLOY

those of the room than at room temperature. The elongation slightly increases, but its change is not marked. The tensile strength, however, increases up to 200 deg. cent. (392 deg. fahr.) and we have samples that increase up to 250 deg. cent. (482 deg. fahr.). At 300 deg. cent. (572 deg. fahr.) one alloy has a tensile strength of 9500 lb. per sq. in., and the other alloy more than 18,000 lb. per sq. in. The second alloy is twice as strong as the first at this temperature with sufficient ductility, over 2 per cent, to make this advantage a decided factor in its use. This alloy is used to some extent at present in experimental cylinders, and also in cylinder-heads and other parts requiring considerable strength at the higher temperatures.

The difference in structure due to a change in the process of manufacture is indicated in Fig. 11. On the left is a section of a piston alloy cast in sand, showing its typical grain size. On the right is the same magnification of the same composition cast in a permanent mold. The permanent mold process produces a very much finer-grained structure. This is another illustration of effecting a change in the structure of a metal which also changes its properties.

COMPARISON WITH OTHER METALS

A comparison of aluminum with machine steel is interesting, especially in connection with fatigue values. The modulus of elasticity of machine steel is 30,000,000, which is indicated by the slope of the straight-line portion of the curve in Fig. 12. An aluminum alloy containing about 4 per cent of copper, 0.5 per cent of magnesium and 0.5 per cent of manganese, has a straight-line graph up to about 20,000 lb. per sq. in., but the slope is quite different from that of the steel stress-strain line. The modulus of elasticity of aluminum is 10,000,000 lb. per sq. in., whereas machine steel breaks sharply after it reaches its elastic limit or yield point, and a slight increase in load produces a large permanent set. The forged aluminum, after passing its proportional limit, continues in such a manner that a slight permanent set produces a marked increase in the elastic limit, so that it has the ability to check its deformation after passing the yield point.

Cast aluminum alloys have the same modulus of elasticity as the forged alloys, but the proportional limit is usually lower, say 7500 lb. per sq. in., as opposed to 22,000 lb. per sq. in. in the forging. But after the cast aluminum reaches its true proportional limit, the curve rises nearly straight for some distance, so that it requires a large increase in load to produce a slight permanent deformation. The whole point of the matter is that the steel takes a large deformation for a slight increase in load, after the yield point; while both cast and forged aluminum stand a large increase in load for a slight increase in deformation, above the yield point.

So far as fatigue values are concerned in the White-Souther tests, something quite unique is noted. A stress-strain diagram of an aluminum casting like the one already mentioned, stressed to 14,000 lb. per sq. in., which is well above its proportional limit, will break after about 500,000 reversals. Stress it to 8500 lb. per sq. in. and it will require 16,000,000 reversals to break it. But mild steel, having a tensile strength of 65,000 lb. per sq. in., an elongation of 30 per cent and a yield point of 30,000 lb. per sq. in., will break at 16,000,000 reversals at a load of only 12,000 lb. per sq. in. Cold-working does not help it. These values are reported by Moore and Putnam, of the University of Illinois, in a report of the National Research Council investigation. The question to be explained is why mild steel will break at say 12,000 lb. per sq. in., which is below the proportional limit, after 16,000,000 reversals, either annealed or cold worked; and why aluminum will stand the same amount, a little above its proportional limit, that is, 16,000,000 reversals. My opinion of this at present, as far as aluminum is concerned, is that the main constituents themselves are well below their fatigue resistance stress, and that the measured proportional limit represents the premature breaking of some of the unfavorably situated brittle constituents in the alloy.

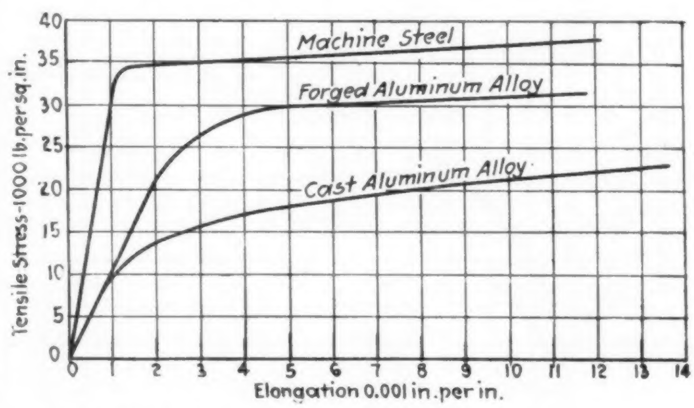


FIG. 12—STRESS-STRAIN DIAGRAMS OF ALUMINUM ALLOYS AND STEEL

I will mention one generality, however, in connection with steel, that seems to represent the consensus of opinion after a considerable amount of experimentation in both England and this country, although it is still awaiting further confirmation, like most of our fatigue data. With a given steel, there are only two ways to increase the fatigue resistance; (*a*) to reduce its grain size by working and low-temperature annealing, or by grain refinement; and (*b*) by heat-treatment. Cold-working does not seem to increase the ability of a given piece of steel to withstand long-sustained fatigue.

FORGING ALLOYS

The forging alloys are mixed like all other aluminum alloys and poured into ingot form; the ingots are either rolled or pressed out into billets, which are then forged into various shapes, as illustrated by Fig. 13. We have found that the forgings give very uniform results. Greater uniformity is secured than was anticipated. Heat-treatment is very beneficial. The untreated alloy may have a tensile strength of about 40,000 lb. per sq. in. and an elongation of about 15 per cent. Properly heat-treated, the alloy will have a tensile strength of about 55,000 lb. per sq. in., an elongation of 20 per cent and an elastic limit of 20,000 lb., or more, per sq. in.

Thus we have a material of about one-third the specific gravity of steel, with the properties of mild steel. We know that, section for section, this does not compare favorably with the alloy steels in their heat-treated condition.

The stiffness or rigidity of a material is a very important factor in many engineering products. Stiffness depends directly upon the modulus of elasticity of a material, and varies as the cube of the thickness of any particular section. Here again aluminum alloys possess advantages as structural members. Making a rough calculation for an aluminum plate of the same weight as a steel plate, the aluminum plate would be about three times as thick. Having one-third the modulus of elasticity, its stiffness would be only one-third insofar as this factor enters; but, being three times as thick as the steel plate, with the same modulus of elasticity, it would be twenty-seven times more rigid; so that we divide the 27 by 3 and get 9 to 1 in favor of aluminum, weight for weight. Actually, for the alloys which are slightly heavier than aluminum, that factor comes out between $7\frac{1}{2}$ and 8 to 1, instead of 9 to 1. If figured the other way, with one-half the weight in plate section, the aluminum would be equally as stiff as steel. This factor is quite important in connection with design for rigidity. Another point, perhaps quite obvious, is that rigidity is in general an indication of stress. Absence of rigidity means deformation, usually elastic deformation, it is true, but the stress is directly proportional to the deformation. Consequently, if the elastic deformation is decreased, the stress also is decreased.

Aluminum forgings seem to have applications for different purposes due to different requirements. One factor is lightness. Where lightness of reciprocating parts is desired, aluminum connecting-rods would perhaps be valuable chiefly because of this factor. At the same time, forged aluminum seems to be a very good bearing material against hard steel, and possibly against medium-hard steel. Accordingly, two advantages can be gained by using aluminum connecting-rods; as a bearing and to decrease weight. Moreover, if the aluminum bears directly on the steel, ideal conditions for cooling the bearing result; as aluminum has very high heat conductivity, it should conduct the heat away from the bearing very rapidly.

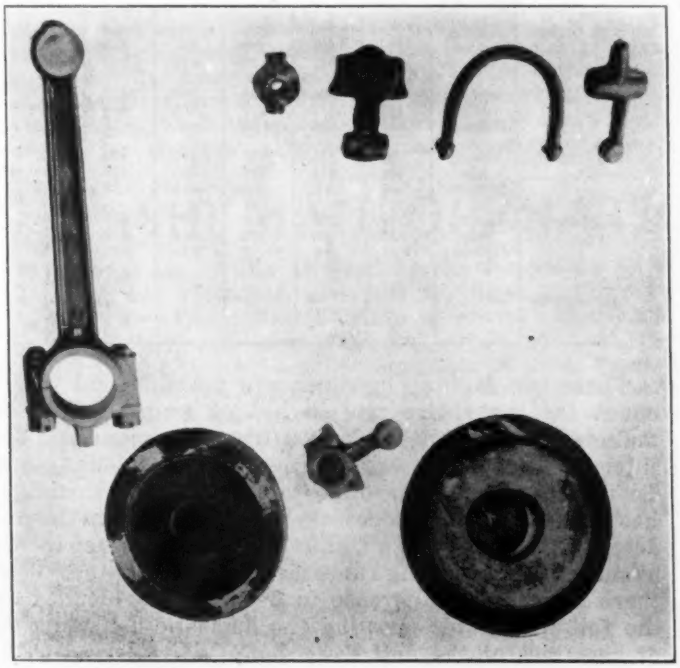


Fig. 13—Miscellaneous Aluminum Alloy Forgings

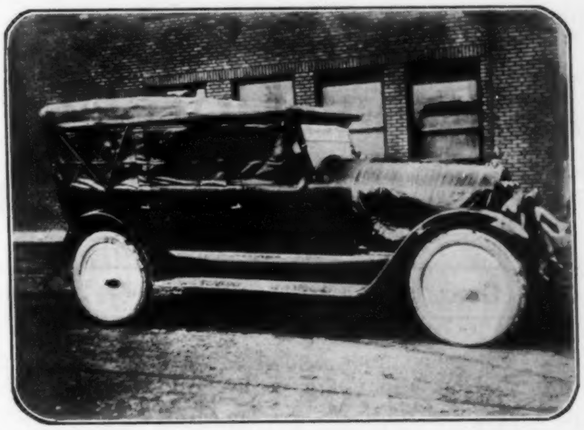


Fig. 14—Aluminum Alloy Disk Wheels

Another important advantage aluminum alloys have, in certain cases, is absence of corrosion. They do not rust like iron. It is true that a coating or oxide forms on the surface of aluminum, but all of the salts of aluminum are white, which is the reason that the oxide of aluminum is inconspicuous. This is true of zinc also. Zinc oxide is white; consequently, when we galvanize a piece of iron, a coating of zinc oxide forms on the outside and we do not think of it as rusting at all. In its way, the zinc is rusted; but the rust is white or colorless. Even though all aluminum products have aluminum oxide on the outside, the oxide is colorless and is also thin.

I will mention briefly some other characteristics of aluminum. One is the coefficient of expansion. In the ordinary timing-gear system the gears might be rigidly attached to one aluminum casting. As aluminum expands about twice as much as iron per degree, it might be found that the iron gears had too great a clearance when the engine is warm. Aluminum gears, or even one aluminum gear, would cut down that clearance, because aluminum has a greater coefficient of expansion. Another characteristic of any of its alloys which I know anything about is that aluminum as a metal seems to be a poor sound transmitter. It does not ring like steel and does not transmit sound and vibration nearly as well as any of the iron products.

Fig. 14 simply represents one additional contemplated use for our newest alloy, Lynite 145, in the form of a cast disk wheel for passenger cars. I say "contemplated use" because it is by no means proved. However, initial tests appear promising because we have been unable, by any means so far devised, to break the wheels in use on a car.

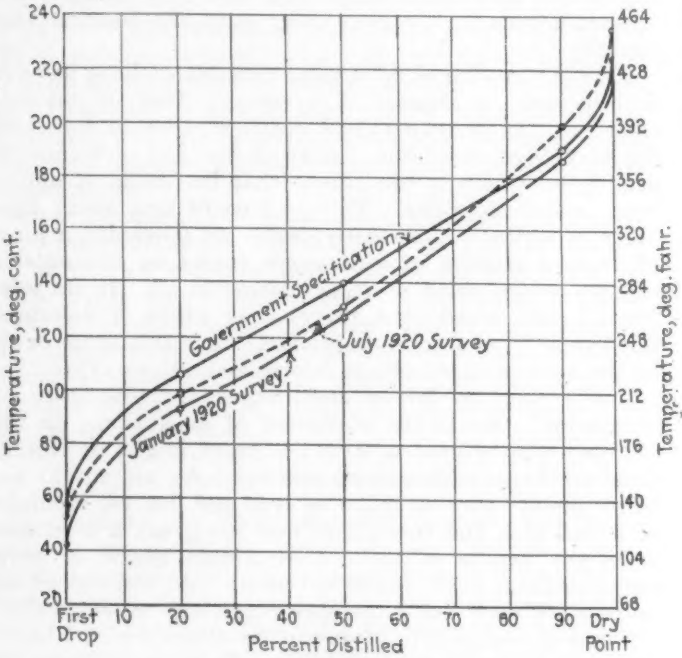
New contemplated uses of this alloy, in this country, are for differential carriers and cast rear-axle housings. These parts are made in Great Britain with considerable success, of two alloys, both containing zinc. One of them is known as the L-5 alloy, used generally for aircraft engines and containing 13.50 per cent of zinc and about 2.75 per cent of copper. The other alloy is known as the British Aluminum Co. standard ingot, containing 10 per cent of zinc and 2.50 per cent of copper. Those alloys form the basis for most of the automotive castings in Great Britain, and differential carriers and rear-axle housings made of them are being used with considerable

(*Concluded on page* 305)

Internal-Combustion Engine Gasoline Survey

By N. A. C. Smith[1] *Illustrated with* Chart

It has been common knowledge in the petroleum industry that the volatility of the gasoline sold in the summer months is less than that of gasoline made and sold in the winter. A year ago, when the Bureau of Mines was making plans to institute semi-annual surveys of the gasolines sold throughout the United States, this fact was taken into consideration. It was decided that the last half of January would be the most satisfactory time to take samples representing the winter grade of gasoline and the last half of July was adopted as the time to take the summer samples. The second semi-annual survey has just been completed and the analytical results apparently show that there has been a greater decrease in the volatility of gasoline than can be accounted for as the normal change from winter to summer quality.



Curves Showing How the Average Distillation of Gasoline Samples Secured in the Bureau of Mines Surveys Compares with the Government Specification

Eighty-two samples were collected from the seven cities of New York, Washington, Pittsburgh, Chicago, New Orleans, Salt Lake City and San Francisco as was done in the first semi-annual survey conducted in January of this year. To indicate just what changes have taken place in the gasolines from the several cities the averages have been compared in the accompanying tables, and in the form of curves which are also shown. On comparing the average for the whole country with the similar average for January 1920, and with the Federal specification, it will be noted that the distillation curve for July 1920, practically parallels the January curve up to about the 75-per cent point. It is considered probable therefore that the change in volatility up to this point is due to the normal variation from winter to summer quality. Above the 75-per cent point, the whole curve rises very rapidly and crosses the curve of the specification for Federal purchases. Part of this rise is undoubtedly normal, as representing the usual seasonal change in quality while part of the increase is due to a few samples which contained much kerosene, thus raising the average of the whole series.

Average Results of Gasoline Surveys
(Temperatures in degrees fahrenheit)

District	Survey	First Drop	20 per cent	50 per cent	90 per cent	Dry Point	Average Boiling Point
New York	January	121	204	256	354	418	261
	July	132	210	263	373	432	272
	Difference	+11	+6	+7	+19	+14	+11
Washington	January	125	200	255	381	439	267
	July	131	200	273	396	449	279
	Difference	+6	none	+18	+15	+10	+12
Pittsburgh	January	100	182	256	375	425	257
	July	128	196	263	400	454	275
	Difference	+28	+14	+7	+25	+29	+18
Chicago	January	116	199	262	381	445	270
	July	142	203	259	399	455	275
	Difference	+26	+4	−3	+18	+10	+5
New Orleans	January	128	206	258	354	424	254
	July	138	223	280	383	445	285
	Difference	+10	+17	+22	+29	+21	+31
Salt Lake City	January	113	204	266	386	440	270
	July	126	212	279	406	456	286
	Difference	+13	+8	+13	+20	+16	+16
San Francisco	January	130	212	258	347	406	262
	July	124	214	264	362	428	270
	Difference	−6	+2	+6	+15	+22	+8
All Districts	January	119	200	259	369	427	264
	July	130	208	268	388	456	277
	Difference	+11	+8	+9	+19	+29	+13
Federal Specifications	Nov. 25, 1919	140	221	284	374	437	...

These two factors, however, are not sufficient to account for the entire rise in boiling points. The remainder is probably due to the increase in demand for internal-combustion engine fuel over previous years. To obtain sufficient gasoline to supply this demand, it has evidently been necessary for the refiners to cut deeper into the crude oil, thus adding somewhat to the amount of high-boiling fuel marketed as gasoline. That there has been an increase in demand is evidenced by the following table showing the domestic consumption of gasoline for the first five months of 1919 and 1920. These figures are taken from the refinery statistics

[1]Petroleum chemist, Bureau of Mines, Washington.

compiled by H. F. Mason, petroleum economist of the Bureau of Mines.

Domestic Consumption of Gasoline in Gallons

	1919	1920
January	169,256,877	238,204,518
February	185,900,192	248,395,214
March	201,004,317	256,020,539
April	243,440,615	297,001,120
May	328,277,648	378,912,672
	1,127,879,649	1,418,534,063
Increase	290,654,414 gal. or 26 per cent	

At least two samples showed evidence of being adulterated with kerosene, while four other samples have end points above 475 deg. fahr., which indicates very careless refining if not actual adulteration. Most of the samples, however, come very close to the average curve. Taken as a whole, the net change in quality is best represented by the increase in the average boiling point of the gasolines, which is given below.

Change in Average Boiling Point
(Temperatures in degrees fahrenheit)

City	January 1920	July 1920	Increase
Chicago	270	275	5
San Francisco	262	270	8
New York	261	272	11
Washington	267	279	12
Salt Lake City	270	286	16
Pittsburgh	257	275	18
New Orleans	254	285	31

The average boiling point also indicates which cities are obtaining the most satisfactory gasoline. From this standpoint, San Francisco is first with an average boiling point of 270, New York is second, Pittsburgh and Chicago are tied for third place and Washington, New Orleans and Salt Lake City follow in the order named.

JAVA AS A MOTOR-VEHICLE MARKET

THE island of Java is an ideal country for motor cars since it has hundreds of miles of well-maintained roads, the slopes in the mountainous regions rarely exceeding 10 per cent. The principal towns, like Surabaya and Semarang, have streets that are practically dust free. At the close of 1919 it was estimated that there were something like 16,000 to 20,000 motor-driven vehicles in Java, Surabaya alone having 4000 cars. Excluding the natives, who usually can afford to buy only bicycles and second-hand motorcycles, these automobiles are owned by Europeans and Chinese, in all about 600,000 persons, which means that there are three automobiles to every 100 persons. One of the least of the troubles of the motorists in Java is gasoline, which is cheap and of very high quality, seldom causing engine trouble. It is made by the local kerosene works, Dordtsche Petroleum Maatschappy, and can be bought in even the smallest villages and in the shops along the main roads at a fixed price. The present price of gasoline is 1.05 to 1.20 guilders for a can of 9 liters; that is, a 2-gal. can sells for about 43 cents, at the normal rate of exchange.

At present there is a good demand for cheap motor cars and a still better demand for medium qualities. Light four-cylinder cars are in demand for service purposes, while the larger and more expensive types are bought for pleasure purposes. The ready sale of these cars seems very often to be a matter of fashion. Just now the demand is for six-cylinder cars, while the four and eight-cylinder cars are not favored for pleasure vehicles and the twelve-cylinder ones are considered to be too expensive even with the cheap gasoline. The cars imported are of several sizes, seating two and three, four and five, and six and seven passengers. The small cars are not so much wanted, the European inhabitants preferring the four and five-passenger cars, while the Chinese like the six and seven-passenger ones. Although a number of limousines are seen, the popular type is the touring car with a heavy canvas hood, which one man can lower. The steering wheel must be at the right side of the car as the traffic regulations require one to turn to the left when meeting another vehicle. The Javanese at present favor a car with one straight line from the engine hood to the back with extra strong mudguards. It might be profitable for American manufacturers to consider seriously the feasibility of shipping only the chassis and the engine and letting the buyer build the body, as an excellent grade of teakwood is plentiful.

Prior to 1919 the transportation of practically all kinds of merchandise was done principally by the old-style bullock carts. This primitive method has given way to modern invention, as the advantages of motor transportation are so many that the extra expense is more or less disregarded. In Surabaya alone there are now more than 100 freight trucks with a capacity varying between 1 and 5 tons each, and it is expected that very soon this number will be doubled if not trebled, as these trucks are able to reach places in the interior of the country where no railroads pass. At present trucks with a capacity of from 3 to 5 tons are much sought.—*The World's Markets.*

AIR MAIL OPERATION COSTS FOR APRIL

THE total cost of the Air Mail Service for the month of April was $55,343.40, according to figures compiled by the Post Office Department. This is an increase of approximately 20 per cent over February, when the cost was $46,004.12, but the increase in the number of miles flown is approximately 5 per cent more, the figures being 47,881 miles for April and 38,158 miles for February. In February the average cost per mile flown was $1.17 on the New York-Chicago route and $1.58 on the route between New York and Washington. In April these were cut to $1.07 and $1.42 respectively. This last series of figures includes overhead as well as flying and maintenance. The comparison of the various items of service and unit costs are given in the accompanying table.

In both sets of figures the cost of work preliminary to the inauguration of service between Chicago and Omaha is included and the figures for April include the cost of assembling one Liberty-twelve engine from salvage and spare parts to be placed in stock and the cost of rebuilding three planes for service on the New York-Washington route.

Air Mail Operation Costs

	New York-Chicago		New York-Washington	
	February	April	February	April
Total cost	$31,774.43	$38,577.33	$14,229.69	$16,766.07
Gasoline, gal	9,352	12,387	4,713	5,803
Flying time, hr.-min	310–26	391–11	115–53	149–56
Total mileage	29,129	36,068	9,029	11,813
Miles flown per gallon	3.1	2.9	1.9	2.0
Cost per hr	$102.36	$98.62	$122.82	$111.78
Cost per mile	$1.09	$1.07	$1.58	$1.42

COW-PUNCHING UPTODATE

THE only striking difference in the ranges and the rangemen of today and of twenty-five or thirty years ago is in the use of the automobile for certain work instead of the cow pony. On many ranches the owner and foremen use flivvers as much as horses for getting over the great ranges. Even line-riders in good country are grasping wheels as much as reins. But you do not see them on the most impressive incidents of cow-punching. At the round-ups or on the market drives no cars are seen. Should a tenderfoot thoughtlessly drive his car into the near vicinity of a round-up bullets would cut into his tires if he did not instantly heed the denunciatory warnings.

New Mexico has nearly 80,000,000 acres and Arizona 73,000,000. Together they occupy more land on the North American continent than all the New England States with Pennsylvania, Ohio and Michigan annexed. The United States Government now holds in vacant public lands in the two States close to 40,000,000 acres, with an additional 20,000,000 in forest reserves, giving 60,000,000 acres available for range stock, although some proportion of that is too rough even for goats. And each State owns vast areas, grants for the maintenance of schools and other public institutions, and of these a very large amount is available for stock grazing. Also the railroads, which were granted every alternate section on a 40-mile wide strip on each side of the right-of-way, have enormous acreage leased or open, on which stock is always running. Then come the Indian Reservations, on most of which very large tracts are permitted to be leased to stockmen. With all these various ownerships fully 90 per cent of the vast areas of the States mentioned is still used for raising and grazing range stock. The other tenth is in improved farms, irrigated or dry.

The range is cut up, it is true, but instead of being cut up by homesteading and irrigation canals and wire fences it is cut up by a diversity of ownership and regulation that did not exist in the old days. The great free range still exists in enormous solid tracts, but it is cut up by various old customs, by "gentlemen's agreements" among the present stockmen and by priority rights. All these do not embarrass the men who are now running stock, the old-established cattlemen with their standard type of cowboys, handling herds of from 5000 to 20,000 steers. They are in the game and know what every card means. The established stockmen do not welcome a newcomer on the range, for they feel perfectly able and willing to utilize every acre with their own stock.

According to a circular recently issued by the Department of the Interior entitled Vacant Public Lands on July 1, 1919, the total of such lands in the eleven cattle or range States is 211,277,473 acres. That is free range, open to every one, for no one but Uncle Sam has any claim or title to it. In addition to that those States have in forest reserves owned by the Government 130,160,000 acres. Almost all this is open for stock grazing under permits which are granted to any stockman, large or small, who first applies for them. In all these eleven range States the improved lands, irrigated or dry, amount to but a trifle over 12 per cent of the total acreage, which is 713,580,200 acres. All outside of that 12 per cent is wild land available for grazing by arrangement with the various owners. The various State governments own millions of acres of the grants they received for the maintenance of schools and institutions. These lands are for sale or lease from time to time. The railroads own millions of acres of grant lands which are also for sale or lease. In all there are over 600,000,000 acres of wild land in the range states, North and South, which are used for stock work. In the figures just given, Texas, the greatest range State of all, is not included. Uncle Sam does not and never owned one section of land in that State, and the conditions of the available lands there are entirely different from those in the other States.—G. F. Stratton in *The Country Gentleman.*

REFINERY OPERATIONS IN MAY

GASOLINE production from the refineries in the United States in May showed a daily average of 12,292,880 gal., an increase of 439,632 gal. over the daily rate of production in the month of April. The gasoline production in May, 381,079,291 gal., was the highest on record. Domestic consumption, however, has increased approximately 82,000,000 gal., or 28 per cent as compared with April. The stocks on hand at the refineries, therefore, were reduced by 65,880,849 gal. in the month, showing that the seasonal demand for gasoline has overtaken the supply and the reduction in stocks for the year has begun. In 1919 gasoline stocks did not start to decrease until in June, or two months later in the season. The exports of gasoline during the month of May were 25,125,000 gal. more than in the preceding month. Shipments to our insular possessions were reduced approximately 727,000 gal., or over 100 per cent as compared with April shipments.

The production of lubricating oils in May reached the highest point on record, 89,252,410 gal., with a daily average of 2,879,110 gal. Lubricating stocks on May 31 were 136,882,485 gal., or a decrease of 37,871,624 gal. since June 1, 1919. The total export movement of lubricating oils for the first five months of 1920 showed a gain of 58,000,000 gal., or a 47-per cent increase over the same period in 1919. The domestic consumption for the first five months of 1920 was 39,000,000 gal., or 21 per cent larger than in 1919.

The increased domestic consumption and foreign demand for refinery products can be taken as an indication of increased industrial activity both at home and abroad.

A SUPERCHARGED ENGINE AND AIRPLANE PERFORMANCE

IN Technical Note No. 2 of the National Advisory Committee for Aeronautics, George de Bothezat discusses the effect upon performance of using a supercharged engine in an airplane. The question is treated in an approximate fashion but one which gives an exact idea of the advantages of supercharging. Two cases are considered, in the first of which an airplane climbs with an ordinary engine without supercharging and afterward is equipped with a supercharged engine.

In both cases the power of the engine at sea level is the same and the propeller efficiency is maintained constant. In the first case the ceiling is reached with an angle of attack of 13 deg. at a speed of 120 ft. per sec. and the value is 25,000 ft. In the second case the power of the engine at sea level is maintained constant up to an altitude of 20,000 ft. by the supercharger but above that height the loss in power is approximately as the density of the air. In this case the ceiling is increased to 37,000 ft. or approximately 50 per cent more than in the previous one where an engine which was not equipped with a supercharger was employed to provide power for the airplane.

A copy of the pamphlet can be secured on application to the National Advisory Committee for Aeronautics, Washington.

Officers and Committee Personnel

THE personnel of the Council of the Society for the current year is given below. This is supplemented by lists of the members of the various Administrative Committees as appointed by President Vincent and the Standards Committee.

Officers and Members of the Council

J. G. Vincent, President
J. G. Utz, First Vice-president
W. G. Wall, Second Vice-president representing motor car engineering
G. L. Martin, Second Vice-president representing aviation engineering
H. C. Buffington, Second Vice-president representing tractor engineering
C. A. Criqui, Second Vice-president representing marine engineering
L. M. Ward, Second Vice-president representing stationary internal-combustion engineering

E. A. De Waters, Councilor
David Fergusson, Councilor
F. M. Germane, Councilor
E. A. Johnston, Councilor
Niran B. Pope, Councilor
A. W. Scarratt, Councilor
C. B. Whittelsey, Treasurer
C. M. Manly, Past President
Coker F. Clarkson, Secretary and General Manager

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Edward Orton, Jr. W. G. Wall

FINANCE COMMITTEE

H. M. Swetland, *Chairman*
E. P. Chalfant G. H. Houston
Christian Girl Alfred Reeves

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Howard E. Coffin, *Chairman*
H. M. Crane J. M. Schoonmaker, Jr.
C. F. Kettering C. M. Vought

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Azel Ames B. G. Koether
B. B. Ayers C. F. Scott

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H. A. Coffin John Younger

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H. C. Sadler G. A. Young

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J. A. Anglada C. B. Veal
J. E. Maloney A. D. Wilt, Jr.

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B. B. Bachman, *Chairman*

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Col. C. de F. Chandler J. L. Harkness
Major V. E. Clark Col. Wm. N. Hensley, Jr.
C. H. Day Commander J. C. Hunsaker
D. W. Douglas C. B. Kirkham
W. L. Gilmore G. C. Loening
F. R. Porter R. H. Upson
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W. T. Thomas P. W. Wittemann

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R. E. Wells

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A. K. Brumbaugh Alfred H. Miller
T. V. Buckwalter H. J. Porter
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L. W. Close Otto Schoenrock
David Fergusson H. C. Snow
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Joseph Bijur W. S. Haggott
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W. A. Chryst B. M. Leece
Bruce Ford A. D. T. Libby
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W. C. Morehead
Guy W. Vaughan

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George W. Hoyt
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C. Oppe
C. T. Perkins
C. S. Sage
A. L. Swank
S. R. Swenson

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F. L. Morse
H. S. Pierce

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E. A. DeWaters
S. P. Hess
Harry R. McMahon
R. A. Schaaf
F. A. Whitten

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Theodore C. Menges
E. B. Newill
L. M. Ward

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Pneumatic Tires for Passenger Cars Subdivision

S. P. Thacher, *Chairman*

W. H. Allen
C. I. Bradley
E. G. Hulse
J. C. Tuttle
W. S. Wolfe

Pneumatic Tires for Commercial Vehicles Subdivision

W. S. Wolfe, *Chairman*

W. H. Allen
C. I. Bradley
L. R. Davis
E. G. Hulse
J. C. Tuttle

Pneumatic Tires for Airplanes Subdivision

W. H. Allen, *Chairman*

C. I. Bradley
A. H. Petersen
S. M. Schott
J. C. Tuttle
W. S. Wolfe

Solid Tires Subdivision

A. Hargraves, *Chairman*

W. H. Allen
C. I. Bradley
L. R. Davis
Hugo Hoffstaedter
A. H. Petersen

Pneumatic Tire Rims Subdivision

C. C. Carlton, *Chairman*

W. H. Allen
E. K. Baker
W. N. Booth
Lewis Fine
J. E. Hale
J. W. Holt
S. M. Schott
J. G. Swain
J. H. Wagenhorst

Solid Tire Bands and Rims Subdivision

W. N. Booth, *Chairman*

W. H. Allen
E. K. Baker
C. C. Carlton
L. R. Davis
Lewis Fine
J. E. Hale
A. Hargraves
J. W. Holt

TRACTOR DIVISION

E. A. Johnston, *Chairman*

H. C. Buffington
L. W. Chase
A. H. Gilbert
R. O. Hendrickson
Alfred Krieg
John Mainland
M. B. Morgan
Dent Parrett
C. B. Rose
A. W. Scarratt

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A. W. Copland, *Chairman*

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L. C. Fuller
A. A. Gloetzner
W. C. Lipe
C. W. Spicer
W. G. Wall
E. E. Wemp
S. O. White

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Francis W. Davis, *Chairman*

Ralph W. Austin
William M. Britton
A. K. Brumbaugh
E. L. Clark
J. R. Coleman
Charles O. Guernsey
L. P. Kalb
H. B. Knap
A. F. Masury
W. T. Norton, Jr.
A. J. Scaife
E. E. Wemp
F. A. Whitten
Capt. G. R. Young

Wheels Subdivision

E. E. Wemp, *Chairman*

R. J. Burrows
E. L. Clark
Herbert S. Jandus
George L. Lavery
Cornelius T. Myers
W. T. Norton, Jr.
J. G. Swain
Herbert Vanderbeek
A. S. Van Haltern

ACTIVITIES OF THE SECTIONS

ON Aug. 12 at Bear Mountain the Metropolitan Section began its spring training for the 1921 baseball season. A varsity and a scrub team began what was intended to be a three-inning game. At the end of the third, however, the score was 9 to 9, necessitating another inning, which gave a score of 11 to 11. Tired but determined, a fifth inning was played resulting in the figures of 19 to 19.

There were some engineers present, however, and a committee of these gentlemen was selected to prove mathematically just who won. As mentioned before, 19 runs were scored by each side. While these figures indicated something they meant nothing, since one side earned its runs and the other side accepted them from the umpire. One side, therefore, had the satisfaction always present in contemplating a job well done. The other side had the equal, if not greater, feeling of contentment due to having "put something over" on their opponents. This, however, is the psychological result, not the mathematical.

Since the nines were composed of eight and six men respectively, it was evident that

$$19 \div 8 = 2.375 \text{ runs per man}$$

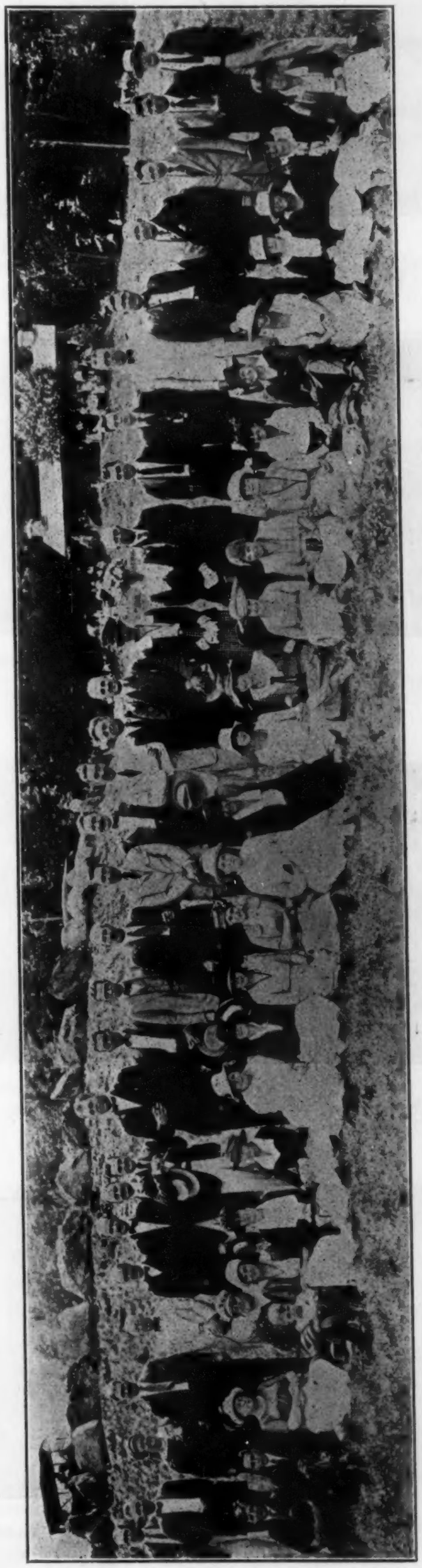
while

$$19 \div 6 = 3.167 \text{ runs per man}$$

While this would indicate that the latter team won, this was not so, since the winning team was at the bat for 120 min. elapsed time, while the losing team used 62 min. less, or 58, thereby winning on time allowance.

Besides the ball game, the members of the Section ate, drank and were merry.

A picture of the teams and their owners appears in the adjacent column.



Outing of the Metropolitan Section to Bear Mountain, Aug. 12, 1920

Sections Officers

Photographs of as many of the Sections officers as it was possible to secure will be found on the following pages.

For the convenience of the members who desire a ready means of ascertaining the addresses of the secretaries of the different Sections a complete list of their names and addresses follows.

Buffalo—Roger Chauveau, 1100 Military Road, Buffalo
Cleveland—A. E. Jackman, 1900 Euclid Avenue, Cleveland
Detroit—M. Howard Cox, 1361 Book Building, Detroit
Indiana—B. F. Kelly, Weidley Motors Co., Indianapolis
Metropolitan—M. C. Horine, International Motor Co., West End Avenue and Sixty-fourth Street, New York City
Mid-West—L. S. Sheldrick, 333 South Dearborn Street, Chicago
Minneapolis—C. T. Stevens, 541 Plymouth Building, Minneapolis
Pennsylvania—H. Hollerith, Jr., Lenox Apartments, Thirteenth and Spruce Streets, Philadelphia

ALUMINUM ALLOYS

(*Concluded from page* 299)

success. There seems to be a tendency in this country for automotive engineers to try to reduce the unsprung weight in the rear part of the car by using more ductile and stronger light alloys, which fulfill the requirements for a modern engineering material more nearly than any aluminum sand castings made heretofore. The modern engineering material is selected to stand abuse rather than normal use.

BUFFALO SECTION

C. F. MAGOFFIN, Chairman — E. T. MATHEWSON, Vice-Chairman — ROGER CHAUVEAU, Secretary — J. C. TALCOTT, Treasurer

CLEVELAND SECTION

H. G. WELFARE, Chairman — H. C. SNOW, Vice-Chairman — A. E. JACKMAN, Secretary — K. B. BRITTON, Treasurer

DETROIT SECTION

E. G. GUNN, Chairman — HOWARD A. COFFIN, Vice-Chairman — M. HOWARD COX, Secretary — E. W. SEAHOLM, Treasurer

INDIANA SECTION

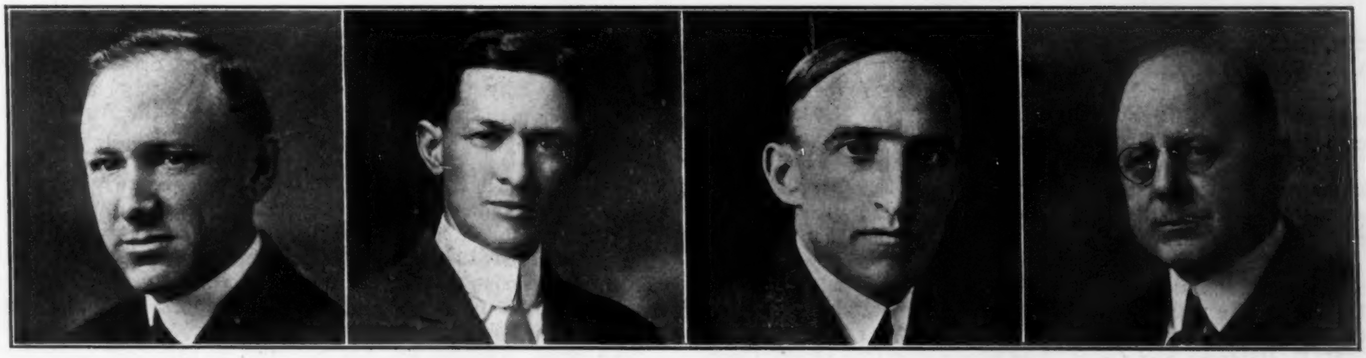
CHESTER RICKER, Chairman — D. L. GALLUP, Vice-Chairman

METROPOLITAN SECTION

A. M. Wolf, Chairman — A. C. Bergmann, Vice-Chairman — M. C. Horine, Secretary — L. G. Nilson, Treasurer

MID-WEST SECTION

George T. Briggs, Chairman — Dent Parrett, Vice-Chairman — L. S. Sheldrick, Secretary — Walter S. Nathan, Treasurer



MINNEAPOLIS SECTION

A. W. Scarratt, Chairman — R. S. Kinkead, Vice-Chairman — C. T. Stevens, Secretary — J. S. Clapper, Treasurer

PENNSYLVANIA SECTION

G. W. Smith, Jr., Chairman — A. K. Brumbaugh, Vice-Chairman — H. Hollerith, Jr., Secretary — J. T. O'Neill, Treasurer

PERSONAL NOTES OF THE MEMBERS

Dickerson G. Baker has resumed his practice as a consulting engineer specializing in methods and equipment for quantity production of metal work and is devoting part of his time to the subject of producing and measuring screw threads. During the war he was associated with the Greenfield Tap & Die Corporation, Greenfield, Mass., as chief engineer and manager of its gage division. Pending the establishment of a permanent office Mr. Baker can be addressed at 153 Church Street, Willimantic, Conn.

John T. Bibb, Jr., who was chief engineer of the Internal Combustion Steam Engine Co., Seattle, Wash., has accepted the position of engineer with the Doud-MacFarlane Machinery Co., Tacoma, Wash.

Lloyd J. Bohan has been appointed general sales manager of the axle department of the Edward Valve & Mfg. Co., Chicago. He was formerly Western sales representative for the Torbensen Axle Co., Cleveland.

Arthur Boor has accepted a position with the Owen Magnetic Motor Car Corporation, Wilkes-Barre, Pa. He was formerly an engineer in the employ of the International Fabricating Corporation, also of that city.

S. S. Bradley has been elected assistant treasurer of the Manufacturers Aircraft Association, 501 Fifth Avenue, New York City. He was formerly general manager of this association.

L. E. Butzman, who was formerly assistant chief engineer of the Tool & Auto Products Co., Cleveland, has been appointed general manager of the Grant Tool & Gage Co., also of that city.

Everett Cavanagh, who was formerly sales engineer with the Bimel Spoke & Auto Wheel Co., Portland, Ind., is now factory manager of the Imperial Wheel Co., Flint, Mich.

John Chulstrom has accepted a position as draftsman in the engineering department of the Chevrolet Motor Co. at its New York City branch.

Arthur L. Collins has resigned as engineer of tests with the Atlas Ball Co., Philadelphia, to accept a position with the Ace Motor Corporation, also of that city.

A. O. Dady, formerly chief engineer with Fansteel Products Co., Detroit, has accepted a position with the Cherington Mfg. Co., Waukegan, Ill.

Clarence M. Foss has accepted a position as service manager with the Willys Corporation, Elizabeth, N. J. He recently received his discharge from the Army.

E. R. Greer, who was formerly mechanical engineer and manager of the service department of the Four Wheel Drive Auto Co., Clintonville, Wis., has been elected vice-president and engineer of the Motor Transport Co., Minneapolis.

C. G. Griffin has accepted the position of supervisor with the Chevrolet Sales Division, General Motors, Ltd., London, England. He was formerly general sales manager for F. S. Bennett, Ltd., also of London.

N. E. Hildreth has resigned as superintendent of the Cushman Motor Works, Lincoln, Neb., to accept the position of works manager of the Witte Engine Works, Kansas City, Mo.

Harry O. King has been elected president of the H. O. King Co., 1145 Diversey Parkway, Chicago, which he has organized to manufacture tools, dies, jigs, special machine tools and automobile parts. He was formerly treasurer and secretary of the Phenix Truck Makers, Inc., also of that city.

B. A. Kononoff has accepted a position as mechanical engineer with the Ingersoll-Rand Co., Phillipsburg, N. J.

G. J. Lang, vice-president of the American Bosch Magneto Corporation, Springfield, Mass., has been elected vice-president and general manager of Gray & Davis, Inc., Boston. He will in the future divide his time between the two organizations.

Walter M. Lipps, who was formerly assistant general manager of the Victory Tractor Co., Greensburg, Ind., is now associated with the United Engineering Co., also of that city, and is located at its general sales office at 1607 Merchants Bank Building, Indianapolis.

G. A. Little has accepted a position in the engineering department of the Red Diamond Motors, Inc., Atlanta. He was formerly an instructor in the Motor Transport Corps Training School at Camp Jesup.

W. J. McIntyre has resigned as sales engineer with the Splitdorf Electrical Co., Newark, N. J., to accept a position with the Van Sicklen Speedometer Co., also of Newark, as sales representative in the Cleveland and Eastern territory.

P. R. Mattix has accepted a position in the production department of the Lafayette Motors Co., Indianapolis.

William H. Meyer has resigned as chief draftsman with the Blue Bird Mfg. Co., St. Louis, to accept a position as layout draftsman with the Dorris Motor Car Co., also of that city.

Raymond P. Miller, who was formerly process man and engineer with the Schwartz-Herrmann Steel Works, Inc.; Somerville, N. J., has accepted a position as inspector and bonus time setter at the Eastern Mfg. Co., South Brewer, Me.

Arthur T. Murray, president of the American Bosch Magneto Corporation, Springfield, Mass., has been elected president of Gray & Davis, Inc., Boston. This follows the arrangement recently made by the stockholders of the latter organization whereby the American Bosch Magneto Corporation assumes immediate executive control.

H. F. Patterson has been appointed assistant chief engineer of the Supreme Motors Corporation, Warren, Ohio. He was formerly a designing engineer with the Rutenber Motor Co., Marion, Ind.

Louis Petersen has resigned as a tool and machine designer with the Cadillac Motor Car Co., Detroit, and is now associated with the Ricker Farm, Lockport, N. Y., of which he is a part owner.

W. H. Radford, chief engineer in charge of engineering and inspection at the Saxon Motor Car Corporation, Detroit, has resigned his position. As yet he has not made any plans for the immediate future.

Paul H. Redin has left the employ of the Rockford Drilling Machine Co., Rockford, Ill., where he was a mechanical draftsman, and has accepted the position of tool designer in the implement division of the Samson Tractor Co., Janesville, Wis.

J. B. Replogle, formerly director of laboratories with the General Motors Corporation, Detroit, has been elected vice-president of the Sunnyhome Electric Co., 755 Scotten Avenue, also of that city.

W. S. Roberts has accepted a position with the Automotive Products Co., 327 South La Salle Street, Chicago. He was formerly a salesman in the New York City office of the Westinghouse Electric & Mfg. Co., East Pittsburgh, Pa.

Ivar L. Shogran has accepted a position as layout man with the Western Aircraft Corporation, Los Angeles, Cal.

M. Frank Strauss has been appointed sales manager of White-Humphries Motor Co., San Francisco. During the war he served in the Ordnance Department and was discharged with the rank of captain.

Van Wyck Hewlett, Jr., has resigned as assistant professor of mechanical engineering, Pennsylvania State College, State College, Pa., to accept the post of assistant professor of mechanical engineering at the Michigan Agricultural College, East Lansing, Mich.

Andrew L. Vargha, who was formerly an engineer with the Louisiana Motor Car Co., Inc., Shreveport, La., has resigned to accept a position as designer with the Pittsburgh Model Engine Co., Pittsburgh.

Edwin C. Walker has accepted a position as development engineer with the Armstrong Spring Co., Flint, Mich. He was formerly designing engineer with the Standard Parts Co., Cleveland.

W. T. Walker has been appointed vice-president and manager of the L. M. Axle Co., Cleveland.

Percival White has severed his connection with the Aluminum Manufactures, Inc., Cleveland, where he held the position of director of development, and is now engaged in consulting engineering work under his own name at 50 Congress Street, Boston.

Fred C. Ziesenheim is conducting research work on internal-combustion engines in the laboratories of the Carnegie Institute of Technology, Pittsburgh.

Applicants *for* Membership

The applications for membership received between July 14 and Aug. 14, 1920, are given below. The members of the Society are urged to send any pertinent information with regard to those listed which the Council should have for consideration prior to their election. It is requested that such communications from members be sent promptly.

ARBUCKLE, SAMUEL F., sales engineer, U. S. Automotive Corporation, *Connersville, Ind.*

ARMSTRONG, J. ALLAN, soliciting agent, Allegheny Steel Co., *Brackenridge, Pa.*

BALTON, CHARLES A., engineer, Charles A. Balton Engineering Co., 41 Perry Street, *Buffalo.*

BARNES, WILLIAM B., assistant in experimental laboratory, Cadillac Motor Car Co., *Detroit.*

BARTLETT, JOHN W., engineer, Chase Tractors Corporation, Ltd., *Toronto, Ont., Canada.*

BATES, MORTIMER F., assistant engineer, Sperry Gyroscope Co., *Brooklyn, N. Y.*

BELL, GEORGE, sales manager and assistant general manager, Teagle Co., *Cleveland.*

BERNHART, EDWIN L., assistant chief engineer, Northway Motors Corporation, *Framingham, Mass.*

BESELIN, H. J., chief draftsman, O. E. Szekely Co., *Moline, Ill.*

BOUCHER, J. D., automotive engineer, Aluminum Manufactures, Inc., *Cleveland.*

BOUSSIGNON, FERDINAND, engineer, F. Boussignon, *Begles, Gironde, France.*

BOWERMAN, J. A., assistant general production superintendent, Fisk Rubber Co., *Chicopee Falls, Mass.*

BRIGGS, JOHN W., superintendent, Cushman Motor Works, *Lincoln, Neb.*

BRIMBLE, GEORGE D., chief draftsman, Transport Truck Co., *Mount Pleasant, Mich.*

BRYANT, HARRY W., assistant engineer, Osgood Bradley Car Co., *Worcester, Mass.*

BURDICK, RALPH M., president, American Engine & Airplane Co., *Los Angeles, Cal.*

BURKE, D. A., president and general manager, Sheridan Motor Car Co., *Muncie, Ind.*

BUSER, WILLIAM CHARLES, shop engineer, Midwest Engine Co., *Indianapolis.*

CLARK, HERBERT, assistant standards supervisor, Aluminum Manufactures, Inc., *Cleveland.*

CORCORAN, LOU A., manager, Zenite Metal Co., *Indianapolis.*

CORSON, H. H., in charge of planning department, Anderson Electric Car Co., *Detroit.*

CRAWFORD, JAMES M., chief engineer, Allen Motor Co., *Columbus, Ohio.*

CRUICKSHANK, JAMES A., chief engineer, Interstate Fdry. Co., *Chicago.*

DAWSON, CHARLES A., service manager, Signal Motor Truck Co., *Detroit.*

DICK, ALBERT, powerplant draftsman, Mexican Oil Co., *New York City.*

DIMEO, JAMES J., general superintendent, Jaxen Co., *Toledo.*

D'ORVILLE, T. L. REEPMAKER, mechanical engineer, Standard Steel Spring Co., *Coraopolis, Pa.*

DUTCHER, F. H., instructor, Columbia University, *New York City.*

DYKSTRA, JAMES, designer, Saxon Motor Corporation, *Detroit.*

ETTENGER, HARRY G., charge of service department, Neel-Cadillac, *Philadelphia.*

FARR, WARREN H., factory manager, Sheridan Motor Car Co., *Muncie, Ind.*

FLOSS, CARL WILLIAM, draftsman, E. A. Nelson Automobile Co., *Detroit.*

FREDRICKSON, W. S., general sales manager, Hart-Parr Co., *Charles City, Iowa.*

FREELAND, HILTON G., metallurgist, Hoover Steel Ball Co., *Ann Arbor, Mich.*

FUNK, JAMES B., branch manager, Champion Spark Plug Co., *Toledo.*

GALLIVAN, JOHN M., student, Syracuse University, *Syracuse, N. Y.*

GILBERT, RALPH M., experimental engineer, Massey-Harris Co., Ltd., *Toronto, Ont., Canada.*

GLENN, JOHN W., president and general manager, Glenmore Co., Inc., *Lima, Ohio.*

GORDON, CHARLES, sales engineer, Foote-Burt Co., *Cleveland.*

GREEN, CLARENCE J., draftsman, Osgood Bradley Car Co., *Worcester, Mass.*

GREINER, RALPH C., assistant engineer, U. S. Tractor & Machinery Co., *Menasha, Wis.*

GRILL, C. H., chief draftsman, Foote Brothers Gear & Machine Co., *Chicago.*

GRIMM, GEORGE EDWARD, chief draftsman, Willys-Overland Co., *Toledo.*

GRUENBERG, OTTO, student, Tri-State College, *Angola, Ind.*

HARTRICK, CHARLES E., experimental engine designer, Liberty Motor Car Co., Detroit.

HARVEY, T. H., works manager, Ohio Steel Foundry Co., *Springfield, Ohio.*

HEBBELIN, LOUIS, draftsman, O. E. Szekely Co., *Moline, Ill.*

HODGIN, ELLIS RAY, sales manager, Southern Truck & Car Corporation, *Greensboro, N. C.*

KOGER, LIEUT. ESTEN B., U. S. N. R. F., Room 2326 Navy Building, *Washington.*

LANDRUM, MARK, JR., mechanical draftsman, Holt Mfg. Co., *Stockton, Cal.*

LIMBOCKER, CHARLES C., president, Wolverine Tube Co., *Detroit.*

LOUPRET, LIONEL N., electrical engineer, Kokomo Electric Co., *Kokomo, Ind.*

MCDONALD, O. R., sales manager, Gibson Co., *Indianapolis.*

MCLAUGHLIN, WILSON, mechanical engineer, Muskegon Motor Specialties Co., *Muskegon, Mich.*

MACKENZIE, MILLER J., test engineer, McCook Field, *Dayton, Ohio.*

MARTY, BENJAMIN F., equipment engineer, Ford Motor Co., *Highland Park, Mich.*

MOGGE, ARTHUR R., manager of advertising sales promotion, Gibson Co., *Indianapolis.*

MOONEY, JAMES DAVID, assistant general manager, Remy Electric Division, General Motors Corporation, *Anderson, Ind.*

NEAL, ARTHUR L., chief draftsman, Peerless Motor Car Co., *Cleveland.*

NELSON, IRA SANBORN, engineer, Hill-Smith Metal Goods Co., *Boston.*

OKEY, PERRY, proprietor, Okey Mfg. Co., *Columbus, Ohio.*

PAGE, EMMETT L., assistant production manager, Oakland Motor Car Co., *Pontiac, Mich.*

PARKHILL, G. B., chief engineer, All American Truck Co., *Chicago.*

PETERSON, E. L., assistant engineer, Falls Motors Corporation, *Sheboygan, Wis.*

PFAUSER, EDWARD M., chief engineer, Texas Motor Car Association, *Fort Worth, Tex.*

QUETSCH, L. J., manager engineering department, A. M. Castle & Co., *Chicago.*

RICHARDSON, IRVIN FOGG, automotive engineer, Vacuum Oil Co., *Boston.*

ROSE, HARRY, business manager, W. D. Block Motor Co., *Grand Rapids, Mich.*

ROSS, FRANK, superintendent pressed steel division, Dodge Brothers, *Detroit.*

SCHARMACH, FRANK WILLIAM, designer and layout man, Transport Truck Co., *Mount Pleasant, Mich.*

SCHLACHTER, DEAN H., Government instructor, *Fort Crook, Neb.*

SIBLEY, B. E., automotive engineer, Continental Oil Co., *Denver.*

SMITH, CHARLES H., sales manager, Allegheny Gear Works, *Pittsburgh.*

SMITH, CHARLES MACCABE, student, Purdue University, *Lafayette, Ind.*

TABB, WARNER T., chief engineer, Duplex Engine Governor Co., *Brooklyn, N. Y.*

TATU, CHARLES F., aeroplane designer and checker, Aeromarine Plane & Motor Co., *Keyport, N. J.*

TAYLOR, ALBERT LE ROY, assistant professor mechanical engineering, University of Utah, *Salt Lake City, Utah.*

TIMIAN, HAL H., assistant engineer, Byrne, Kingston & Co., *Kokomo, Ind.*

TOULMIN, HARRY A., JR., patent lawyer, Toulmin & Toulmin, *Dayton, Ohio.*

TOWNSEND, H. A., director Y. M. C. A. automobile school, *Newark, N. J.*

TRAVI, JOHN J., proprietor, General Storage Battery Service Co., *Philadelphia.*

TREVOR, KARL ROBERT, laboratory engineer, H. H. Franklin Mfg. Co., *Syracuse, N. Y.*

WATANABE, R., gasoline engine designer, Tokyo Gas & Electric Co., *Omori, Tokyo, Japan.*

WATTS, W. A., chief of experimental department, Massey-Harris Co., *Toronto, Ont., Canada.*

WEBB, BERTRAM B., draftsman, Maxwell Motor Co., *Detroit.*

WEINBERG, FRED, consulting engineer, General Motors Corporation, *Detroit.*

WHITALL, LAWRENCE W., district sales manager, Byron Engineering Works, *Louisville, Ky.*

WILLIAMS, FRANK, draftsman, Stout Engineering Laboratories, *Detroit.*

WILLIAMS, LE ROI J., counsel and assistant to general manager, Lincoln Motor Co., *Detroit.*

WILSON, STERLING O., assistant chief draftsman, Glenn L. Martin Co., *Cleveland.*

WISE, N. A., chief engineer, Transport Truck Co., *Mount Pleasant, Mich.*

WYMAN, EDWARD EARLE, motor truck sales, American La France Fire Engine Co., *Elmira, N. Y.*

YAMAGATA, J., gasoline engine designer, Tokyo Gas & Electric Co., *Omori, Tokyo, Japan.*

ZIEBELL, A. C., secretary, Universal Fdry. Co., *Oshkosh, Wis.*

Applicants *Qualified*

The following applicants have qualified for admission to the Society between July 10 and Aug. 10, 1920. The various grades of membership are indicated by (M) Member; (A) Associate Member; (J) Junior; (Aff) Affiliate; (E S) Enrolled Student; (S M) Service Member; (F M) Foreign Member.

AFFLECK, BERTRAM L. (A) general manager of service, Packard Motor Car Co. of Boston, 1089 Commonwealth Avenue, *Boston*.

ALLAN, ROY C. (M) engineer, Stromberg Motor Devices Co., 64 East Twenty-fifth Street, *Chicago*.

BABBITT, PERCY W. (J) electrical research engineer, Simms Magneto Co., *East Orange, N. J.*, (mail) 210 Renshaw Avenue.

BIHL, WILLIAM E. (J) layout draftsman, Iron Mountain Co., *Chicago*, (mail) 7021 Vernon Avenue.

BINDING, JOHN M. (J) assistant chief tool designer, McBarron & Mitchell Tool Co., *Dayton, Ohio*, (mail) 30 North Wilkinson Street.

BIXBY, LEO A. (J) designing engineer, Fuller & Sons Mfg. Co., *Kalamazoo, Mich.*, (mail) 1311 Oak Street.

BONDAR, A. K. (M) designer, Hannevig Sikorsky Aircraft Co., *New York City*, (mail) 9 East Eighty-fifth Street.

BOOTH, EARL C. (M) president and general manager, Booth Engineering Corporation, *Indianapolis*, (mail) 2342 Park Avenue.

BOYD, CHARLES F. (J) chemist and metallurgist, Lafayette Motor Co., Mars Hill, *Indianapolis*.

BRAMHALL, MAYNARD (A) sales engineer, Hyatt Roller Bearing Co., *Detroit*, (mail) 26 Alfred Street.

BUETTNER, WALTER J. (A) secretary, Bendix Engineering Works, *South Bend, Ind.*

CARLSON, ERNEST F. (J) draftsman, Hart-Parr Co., *Charles City, Iowa*.

CHAMBERS, JOHN LAWRENCE (J) engineering, Gray-Dort Motors, Ltd., *Chatham, Ont., Canada*, (mail) 194 Lacroix Street.

CHULSTROM, JOHN (E S) student, Purdue University, *Lafayette, Ind.*, (mail) 72 East Ninety-sixth Street.

CLINEDINST, W. W. (E S) Stevens Institute of Technology, *Hoboken, N. J.*

COCHRAINE, WILLIAM F. (M) president, Curtis Bay Copper & Iron Works, *South Baltimore, Md.*

CRAWFORD, DAVID FRANCIS (M) president, Westinghouse Union Battery Co., *Swissvale, Pa.*

CRAWFORD, MELVIN W. (M) sales engineer, Edward A. Cassidy Co., New York City, (mail) 211 Leicester Court, *Detroit*.

CRITCHFIELD, R. M. (M) assistant chief engineer, Dyneto Electric Corporation, *Syracuse, N. Y.*, (mail) 101 Trinity Place.

DEAN, DAVID MERLIN (A) tester, Hudson Motor Co. of Illinois, *Chicago*, (mail) 4702 North Bernard Street.

DEARBORN, RICHARD JEWELL (A) patent attorney, Texas Co., 17 Battery Place, *New York City*.

DOW, HAROLD T. (M) superintendent, Spring Perch Co., *Stratford, Conn.*

DULANY, GEORGE WILLIAM, JR. (A) president, Climax Engineering Co., Clinton, Iowa, (mail) 511 Harris Trust Building, *Chicago*.

ECKERSON, R. M. (M) service engineer, Continental Motors Corporation, *Detroit*.

EKBLAW, K. J. T. (M) engineering editor, Phelps Publishing Co. and Orange Judd Co., *Chicago*, (mail) 30 North Michigan Boulevard.

FISCHER, HERBERT G. M. (J) assistant research engineer, Klaxon Co., *Newark, N. J.*, (mail) 22 Central Avenue.

FLOWER, ROSWELL B. (M) assistant sales manager, Standard Steel Castings Co., Cleveland, (mail) 910 South Michigan Avenue, *Chicago*.

FRASER, HARRY (M) engineering department, Oakland Motor Car Co., *Pontiac, Mich.*, (mail) Orchard Lake, R. F. D. No. 5.

GASCHE, KARL W. (M) chemical engineer, Westinghouse Union Battery Co., *Swissvale, Pa.*

GEORG, JOSEPH C. (J) engineer, J. B. Norton Co., Inc., *Utica, N. Y.*, (mail) 20 Prospect Street.

GILL, THOMAS B. (A) sales engineering department, Firestone Tire & Rubber Co., *Akron, Ohio*, (mail) Box 353, Firestone Park Station.

HIPPEE, H. P. (M) Union Improvement Co., 607 Mulberry Street, *Des Moines, Iowa*.

HODGE, EDWIN, JR. (M) vice-president, Pittsburgh Knife & Forge Co., North Side, *Pittsburgh, Pa.*

HOMMEL, CHARLES LESTER (A) chief inspector, tractor division, Ford Motor Co. of Delaware, Dearborn, Mich., (mail) 4645 Oregon Avenue, *Detroit*.

HOOD, DONALD T. (M) sales manager, Hood Rubber Co., Watertown, Mass., (mail) 77 Warren Street, *Brookline, Mass.*

JULSRUD, ROLF S. (J) mechanical draftsman, Shaw-Enochs Tractor Co., *Minneapolis*, (mail) 3149 Fremont Avenue, South.

JURS, ALBERT E. (M) manager of production, Fageol Motors Co. of Ohio, *Oakland, Cal.*, (mail) 580 Capell Street.

KEENAN, VINCENT E. (J) assistant research engineer, Fifth Avenue Coach Co., 10 East 102nd Street, *New York City*.

KING, COSBY (A) draftsman, Superior Motor Truck Co., *Atlanta, Ga.*

KLEI, HERBERT EDWARD (J) student mechanical engineering, Tri-State College, *Angola, Ind.*, (mail) 509 West Maumee Street.

KLOSSNER, ROBERT (J) student, Michigan State Auto School, Detroit, (mail) 105 North Mechanic Avenue, *Alliance, Ohio*.

KRAUS, GEORGE A. (A) engineering department, Champion Spark Plug Co., Toledo, Ohio, (mail) Room 304, 616 South Michigan Avenue, *Chicago*.

LAY, ROBERT P. (M) special engineer, H. H. Franklin Mfg. Co., *Syracuse, N. Y.*, (mail) 733 Ackerman Avenue.

LUCAND, ALEXANDER (M) designer, engineering department, International Motor Co., *New York City*, (mail) 513 West 134th Street.

LYON, NORMAN WILLIAM (A) assistant engineer in charge of design, Knox Motors Co., *Springfield, Mass.*, (mail) 32 Maynard Street.

MCBETH, JAMES R. (M) chief draftsman, Gramm-Bernstein Motor Truck Co., *Lima, Ohio*, (mail) 986 Brice Avenue.

MCCALEB, SAMUEL NOEL (A) truck sales manager, Southwest Nash Motors Co., 1134 Broadway, *New York City*.

MCDONALD, ALOIS J. (A) manager of sales, Lebanon Steel Foundry, Lebanon, Pa., (mail) 1418 Walnut Street, *Philadelphia*.

MARTIN, ROBERT H. (A) secretary, treasurer and general manager, Southern Oakland Co., *Atlanta, Ga.*, (mail) 270 Peachtree Street.

MAURER, VERNON H. (A) sales engineer, Stewart-Warner Speedometer Corporation, *Chicago*, (mail) 914 Leland Avenue.

MEISTER, FIRST-LIEUT. LOUIS G. (S M) engineering division, Air Service, McCook Field, *Dayton, Ohio*.

MORAND, JOSEPH J. (M) president, Morand Cushion Wheel Co., 800 South May Street, *Chicago*.

MORE, ARTHUR S. (M) president and general manager, Denby Motor Truck Co., *Detroit*.

PEEL, WILLIAM E. (M) works manager, British Ensign Motors, Ltd., *London, N. W.* 10, *England*.

PRICE, W. T. R. (M) automotive engineer, International Motor Co., *New York City*, (mail) 55 East Fifty-ninth Street.

ROCHE, CLIFTON ROSS (M) automotive engineer, Hamlin Holmes Motor Co., 29 South La Salle Street, *Chicago*.

ROWLES, WILLIAM CHARLES (A) production manager, Frigidaire Corporation, 725 Scotten Avenue, *Detroit*.

SALADIN, HARRY J. (M) vice-president, Glenmore Lubricant Co., 227 South Central Avenue, *Lima, Ohio*.

SANDERSON, CLIFFORD W. (J) chief chemist, Fisk Rubber Co., *Chicopee Falls, Mass.*

SAVAGE ARMS CORPORATION (Aff) 50 Church Street, *New York City*. Representatives: Charles A. Nelson, consulting engineer; F. R. Schaefer, sales manager.

SAYRE, GORDON B. (M) designer, Packard Motor Car Co., *Detroit*, (mail) 1209 Cass Avenue.

SNYDER, JAMES HAWLEY (J) draftsman, Selden Truck Corporation, *Rochester, N. Y.*, (mail) 69 Somerset Street.

SORENG, E. M. (M) sales manager and consulting engineer, Briggs & Stratton Co., *Milwaukee*.

SOUTHMAYD, LEON N. (A) manager of truck tire sales, Fisk Rubber Co., *Chicopee Falls, Mass.*

STELLMAN, L. M. (M) chief engineer, H. H. Franklin Mfg. Co., *Syracuse, N. Y.*

STENGEL, H. IVAN (A) service engineer, Detroit Cadillac Motor Car Co., *New York City*, (mail) 245 West Sixty-seventh Street.

STOVALL, ALBERT R. (M) chief engineer, Dearborn Truck Co., *Chicago*, (mail) 8401 South Peoria Street.

THOMS, LANSING WILT (J) transportation engineer, Thomas J. Doyle Co., *Detroit*.

TINDALL, WILLIAM L. (A) purchasing agent, Chevrolet Motor Co., 224 West Fifty-seventh Street, *New York City*.

TORREY, DANA H. (A) sales manager, Bearings Service Co., 733 Cass Avenue, *Detroit*.

TRASK, HENRY KEITH (M) works manager, Clark Tructractor Co., *Buchanan, Mich.*

TYLER, HARVEY E. (M) student, Waterloo Gasoline Engine Co., *Waterloo, Iowa*, (mail) 202 Randolph Street.

VANDERLIPP, N. F. (J) draftsman, Alexander Klemin, 22 East Seventeenth Street, *New York City*.

VAN DEUSEN, WALLACE M. (M) supervisor of motor vehicles, New York Telephone Co., New York City, (mail) 593 East Seventeenth Street, *Brooklyn, N. Y.*

VOLZ, GEORGE REX (J) technical editor Class Journal Co., 2105 Mallers Building, Chicago, (mail) *Arlington Heights, Ill.*

WEINBERGER, HERMAN H. (A) technical correspondent, General Motors Export Co., *New York City*, (mail) 238 West 122nd Street.

WHITACRE, WALTER (J) chief draftsman, Arvac Mfg. Co., *Anderson, Ind.*, (mail) 2103 Arrow Avenue.

WILLIAMS, PAUL (M) service manager, H. H. Franklin Mfg. Co., *Syracuse, N. Y.*, (mail) 207 Comstock Avenue.

WILLIAMS, T. WALLEY (M) engineer of forging specialties, Carnegie Steel Co., *Pittsburgh*.

WILSON, H. D. (A) vice-president, Herschell-Spillman Motor Co., *North Tonawanda, N. Y.*